Factors affecting the development of mathematical concepts in children with spina bifida and hydrocephalus

Thesis

FACTORS AFFECTING THE DEVELOPMENT OF MATHEMATICAL CONCEPTS IN CHILDREN WITH SPINA BIFIDA AND HYDROCEPHALUS.

Thesis submitted to the Open University for the degree of Doctor of Philosophy in the Faculty of Educational Studies (Psychology of Education).

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No part of this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institution of learning.

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Abstract.

Previous research (Tew and Laurence 1972) suggested that children with Spina Bifida and Hydrocephalus had particular difficulties in the development of mathematical concepts. This research considered factors which may affect such development and consisted of two main sections.

Firstly research was carried out in a school for physically handicapped children. This involved the use of the Young Group Mathematics Test with groups within the school, and detailed case studies of nine children with Myelomeningocele and Hydrocephalus, all of whom were in the same year group. Secondly, large scale data on approximately 600 children with Spina Bifida, from Sheffield Children's Hospital, was analysed. The analysis was broken down into groups based on diagnosis, these being; Myelomeningocele with and without shunts and Meningocele. They were also sub-divided into four groups based on ability in arithmetic as measured on the WISC. A large number of variables and their relationship to arithmetic were considered. The main variables were diagnosis, presence of shunt, ventricle-brain ratio, thickness of neonatal cortex, circumference of head at birth, mobility, level and extent of lesion, continence, intelligence and school placement. Frequently the children with the greatest degree of Hydrocephalus are also the most physically handicapped so additional data for children diagnosed as having 'Congenital' Hydrocephalus only was employed to try and separate out the effects of mobility from the other neurological variables.

The data led to the conclusion that it is the neurological damage present in children with Hydrocephalus which has the most direct effect on the development of mathematical concepts, although this would be influenced by the degree of physical disability and related environmental factors. Suggestions are made as to how to help these children to develop mathematical concepts. An early start is recommended regarding the training of selective attention to attempt to overcome the distractibility which is a frequent concomitant of neurological damage. After this a carefully structured approach to the teaching of maths is recommended.

However, since the most significant correlations with maths ability were with neurological damage, preventative measures must also be concerned with the immediacy and efficacy of shunt surgery.

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INTRODUCTION.

An introduction to the research.

This research arose from an essentially practical problem experienced in a school for physically handicapped children of which about one third had Spina Bifida and Hydrocephalus.
The problem was that these children seemed to have difficulty in coping with mathematical ideas(basically number) even when they showed a reasonable level of intelligence in reading and related activities. If the children concerned had all been unable to read as well as unable to cope with numbers then a basically low intellectual level may have been the cause, but in a number of cases the children were reading at a level above their chronological age. There were obviously other variables at work as well as intelligence, and in order to work out suitable teaching strategies for these children it was necessary to try to discover what these variables might be and how they could affect the development of mathematical concepts.
Thus school based research was begun with this aim in view and was then extended. Additional large scale data from Sheffield Children's Hospital was considered to see if general factors could be drawn out.

CHAPTER ONE. SPINA BIFIDA.

Part 1. Development of the central nervous system; Spina Bifida as a defect in this development.

Development of the central nervous system; Spina Bifida as a defect in this development.

General development of the nervous system. (Figs.1-4)

In the developing embryo the dorsal surface of the embryonic plate is flat at first and then develops neural ridges with neural tissue spreading from these ridges to form nerves later on. In time the ridges come together and form a tube. This occurs first in the middle and then gradually spreads towards the ends. There are also two neural crests formed on the dorsal side of the tube which remain inside the spinal cord. The neural tube starts by being surrounded by a single layer of cells but develops two more layers, with more development taking place laterally than dorsally or ventrally. Most of this neural tube develops into the spinal cord but at the head end it develops into the brain. At first the brain develops three vesicles but this very rapidly becomes five, at which stage the tube starts to bend, and kinks form. When the three vesicles are in existence additional grey matter in the surface of the vesicles develops into the cerebrum (forebrain), tectum (midbrain), and cerebellum (hindbrain). Between the spinal cord and the upper reaches of the brain is the brainstem which is the major integrating centre in lower animals, but has lost a lot of these functions to the cerebral cortex in man. It still contains all the fibre systems interconnecting higher brain structures and the spinal cord, most cranial nerves and their nuclei, and nuclei concerned with vital functions. The ascending reticular activating system forms a core to the brain stem (Rose 1976).

Cerebro-Spinal Fluid.

The canal in the centre of the spinal cord and the ventricles in the brain all contain cerebro-spinal fluid which is manufactured by the choroid plexuses in the large ventricles. About 500 millilitres of the fluid is formed each day with the total volume in man at any one time being about 140 millilitres. Thus the fluid is probably renewed every six to eight hours (Milhorat 1972). The cerebro-spinal fluid circulates throughout the ventricles and the neural tube and is added to mainly in the lateral ventricles. It escapes through the thin roof of the fourth ventricle and

Development of the Central Nervous System.

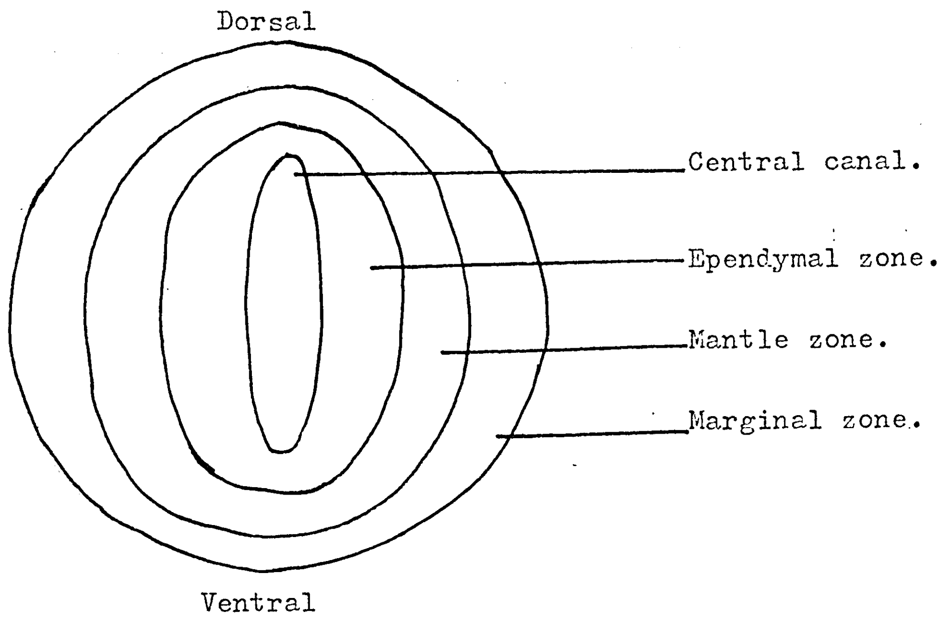


Fig.1. Diagram to show the early development of the neural tube.

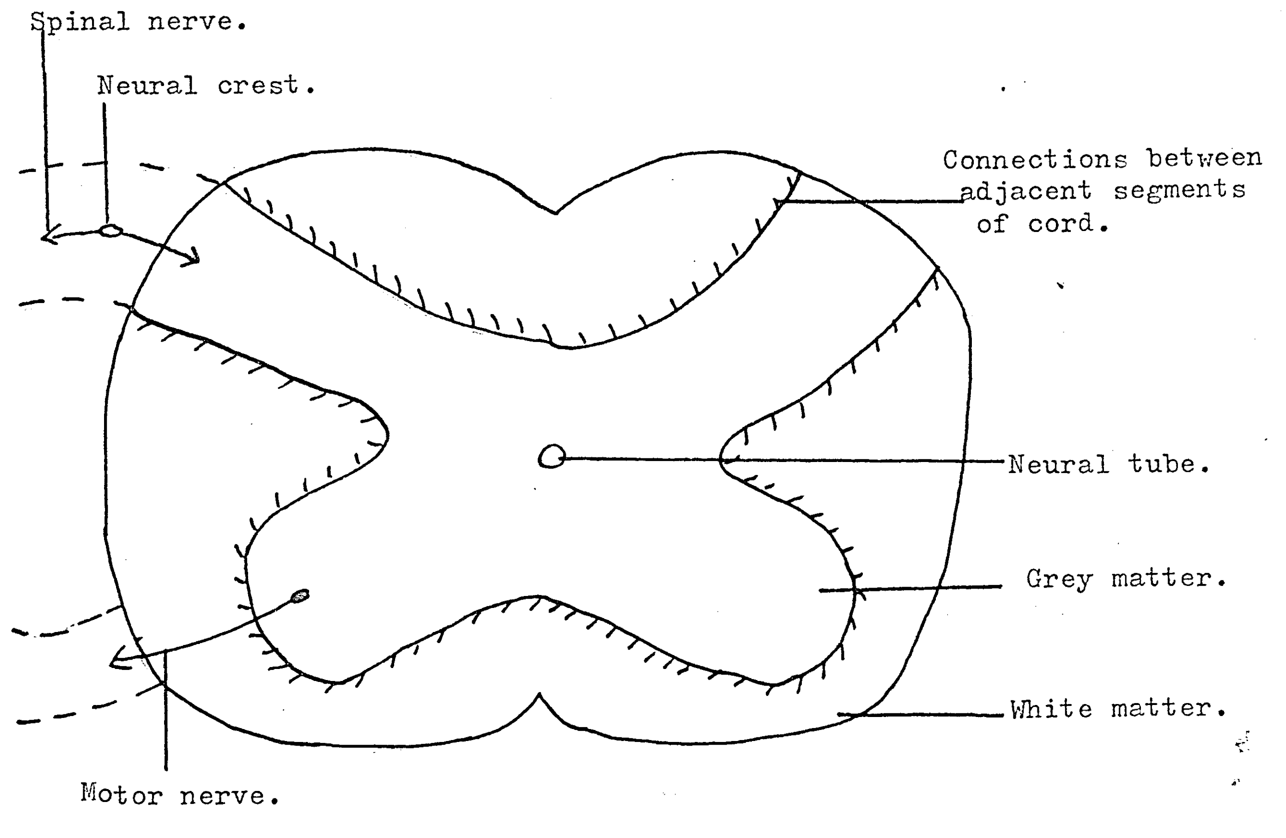
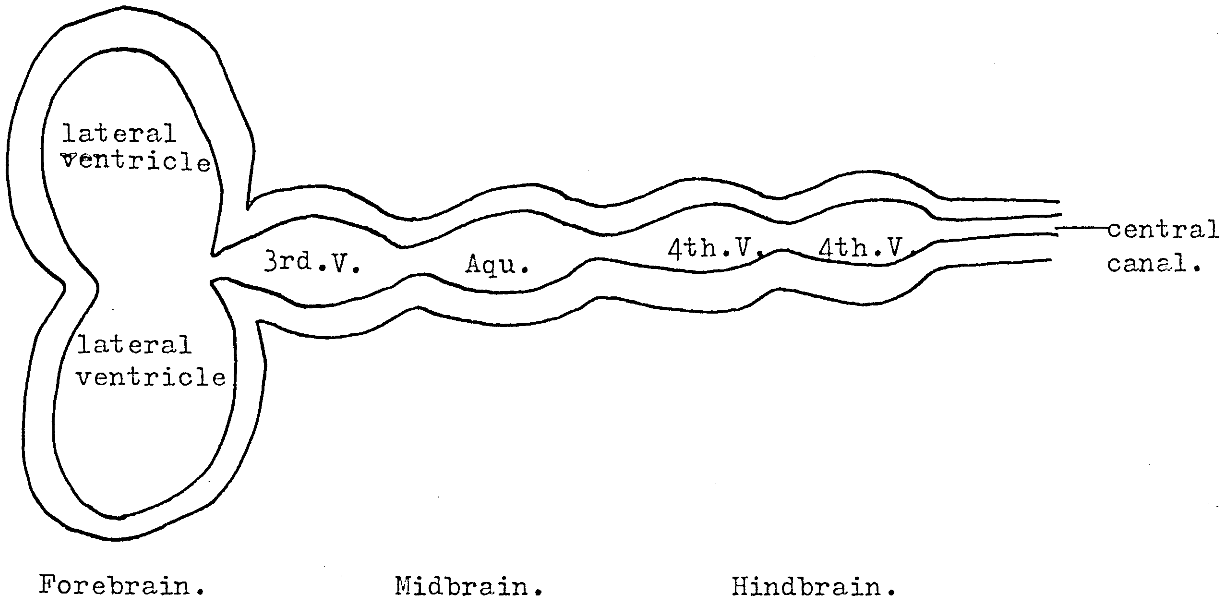


Fig.2. Diagram to show the final stage of development of the neural tube in the area of the spinal cord.

Development of the Central Nervous System.



Key

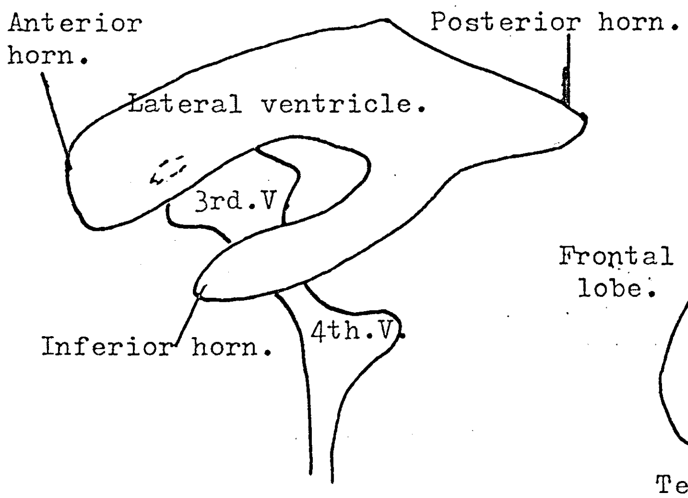
3rd.V. 3rd Ventricle.

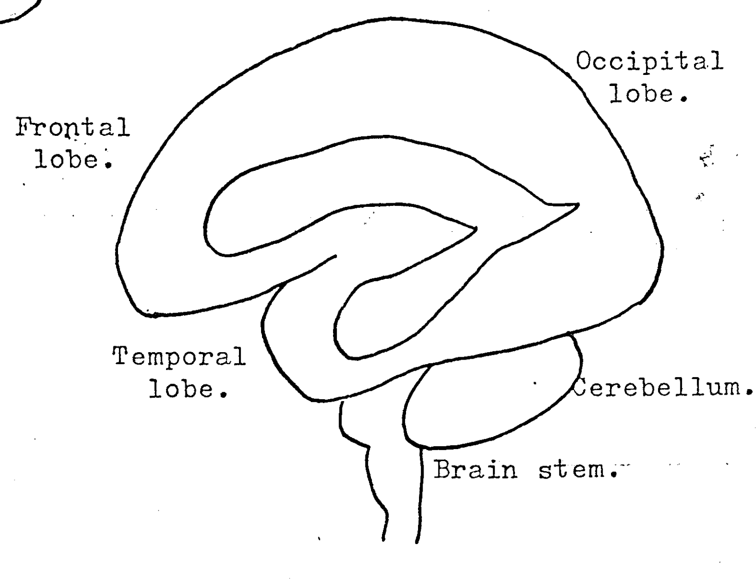
4th.V. 4th Ventricle.

Aqu. Aqueduct of Silvius.

Fig.3. The five vesicle brain at the anterior end of the neural tube: an early stage of brain development.

Fig.4. The arrangement of the ventricles in the fully developed brain.





lies under the arachnoid mater to bathe the surface of the brain. When it reaches the dural sinuses, which are folds in the meninges containing blood, it rejoins the blood stream. It enters the dural sinus through villi which have a simple valve so that the blood cannot flow outwards. The circulation is from the inside to the outside of the brain. If the holes in the roof of the fourth ventricle don't appear the C S F flow is obstructed and dilatation of the ventricles may occur. One view of the development of Spina Bifida suggests that dilatation occurring in both the brain and the spinal cord due to obstruction of the C S F causes Spina Bifida to develop in the lower part of the spine because this is the last part to close (Gardner 1968). This is not a universally held view and it must be remembered that there are various forms of Spina Bifida. These can involve lack of fusion of the bone, or of the neural tube itself, and may not always be associated with an accumulation of cerebro-spinal fluid.

Brain function in early life.

From early foetal life the brain is nearer to the adult gross weight than any other organ except the eye. At birth it is 25% of the adult weight, at six months 50%, at 2½ years 75%, at 5 years 90% and at 10 years, 95%. The weight of the whole body is 5% of adult weight at birth and 50% at 10 years (Tanner 1964, Rose 1976).

Different parts of the brain grow at different rates with a caudo-cranial (tail to head) development. In the motor areas of the brain the nerve cells controlling the arms and upper trunk develop before the cells controlling the legs, and in early development the arms are always ahead of the legs. The main growth spurt for the cerebellum, which is involved in the control of movement, is over by the age of one (Rose 1976).

The newborn baby acts as a sub-cortical organism despite the presence of a considerable amount of cortex which gives it a large brain for its body size (Rose 1976). However it seems that usage is necessary to develop the connections and cause myelination to take place, which causes a further increase in brain weight.

Rose (1976) points out that the motor activity of a three year old child will be in advance of its sensory processing ability and motor activity concerned with the hand and upper body will have developed the most. By fifteen months the motor cortex is still ahead and the occipital cortex is comparatively undeveloped. This is the area which processes information about objects in the centre of the field of vision, whereas the periphery is dealt with sub-cortically. At this stage the child's attention is easily diverted. The basic bodily functions are controlled sub-cortically and it seems likely that the newborn baby is essentially a split brain organism(Gazzaniga 1970). This alters rapidly in most cases but it is possible for someone with a split brain to appear normal because by seeing what both halves of his body are doing he can compensate. However the problems show when complicated tasks requiring integration are demanded (Sperry 1969). The whole concept of brain function is controversial and will be dealt with later.

Spina Bifida.

Brocklehurst(1976) suggests that the structural abnormalities of Spina Bifida and Hydrocephalus are established by about the 28th day of development of the embryo,and that these occur within the basic developmental pattern of the central nervous system and its surrounding mesoderm,with secondary mechanical and hydrodynamic forces producing further deformities in utero.No cause has yet been established but it seems likely that Spina Bifida is caused by some environmental factor,which may or may not be specific, acting upon a genetically susceptible embryo around this 28 day stage. This could affect a number of embryological processes and the exact time of the disturbance in embryogenesis could be the crucial factor. If it occurs at the time of anterior neuropore closure, Anencephaly or Cranium Bifidum will occur but if it coincides with posterior neuropore closure the Spina Bifida lesions will occur in the thoracic,lumbar or sacral regions. On the whole the more extensive lesions of the thoraco-lumbar spine are associated with a greater degree of cerebral malformation than lesions in other parts of the spine(Brocklehurst 1976). It is important at this stage to remember that the congenital deformities grouped as Spina Bifida because they have in common the separation of the vertebral elements in the midline,cover a wide range from Spina Bifida Occulta with such a minimal amount of neurological involvement that it may go undetected,to gross spinal malformation with major neurological involvement in myelomeningocele. The varieties included suggest a disturbed embryogenesis in several directions rather than just one. The development of the spinal cord has already been discussed and while this is developing from the neural tube the surrounding mesoderm becomes segmented and eventually forms the vertebral column,as well as the blood vessels and meninges of the spinal cord. In all forms of Spina Bifida some part of this process is deranged (Brocklehurst 1976). He also mentions the fact that in any neural tube defect some part of the nerve cord fails to close and at that point the supporting tissues such as the vertebrae or cranium also develop abnormally.

The neurological level of the defect affects the extent of the disability.For instance if the lesion occurs at the level of the sixth thoracic vertebra only the upper extremities will have motor power whereas if it occurs in the fourth sacral vertebra there may be no loss of motor power at all. However there is often damage to the spinal cord above the level of the lesion and this can also affect motor power(Emery and Lendon 1973). The most common area for the lesion is the small of the back where a swelling will be present at birth(Menelaus 1980).

Types of Spina Bifida.(Fig.5)

Spina Bifida Occulta.

This is the mildest form of Spina Bifida with the term being used when the normal skin covers the lesion resulting in it being more or less hidden. X-rays of the lumbar spine frequently reveal minor degrees of Spina Bifida Occulta affecting the lower lumbar or upper sacral vertebrae of otherwise normal persons(Brocklehurst 1976). Menelaus(1980) suggests that it may be present in as many as 10% of the population. Spina Bifida Occulta is of more significance when the skin has an abnormal tuft of hair, or is dimpled, pigmented or prominent due to a swelling beneath the skin.

Spina Bifida Cystica.

There are two sub-divisions within this category which vary greatly in their severity.

Meningocele.

In this form of Spina Bifida there is a defect in the vertebral arches through which a swelling which includes the meninges protrudes. The spinal cord is entirely confined to the vertebral canal but may exhibit abnormalities (Menelaus 1980). There may be an associated dysplasia of the neural tube derivatives lying within the spinal canal and beneath the neck of the meningocele(Brocklehurst 1976). The baby will be born with a small swelling on its back at the point where the lesion occurs and this can usually be easily corrected surgically. The amount of damage to nerves and therefore the extent of the paralysis depends on any associated abnormalities of the spinal cord. Menelaus(1980) states that Hydrocephalus is rare in this group.According to Anderson and Spain(1977), who worked in London, 15-25% of the surviving children with Spina Bifida

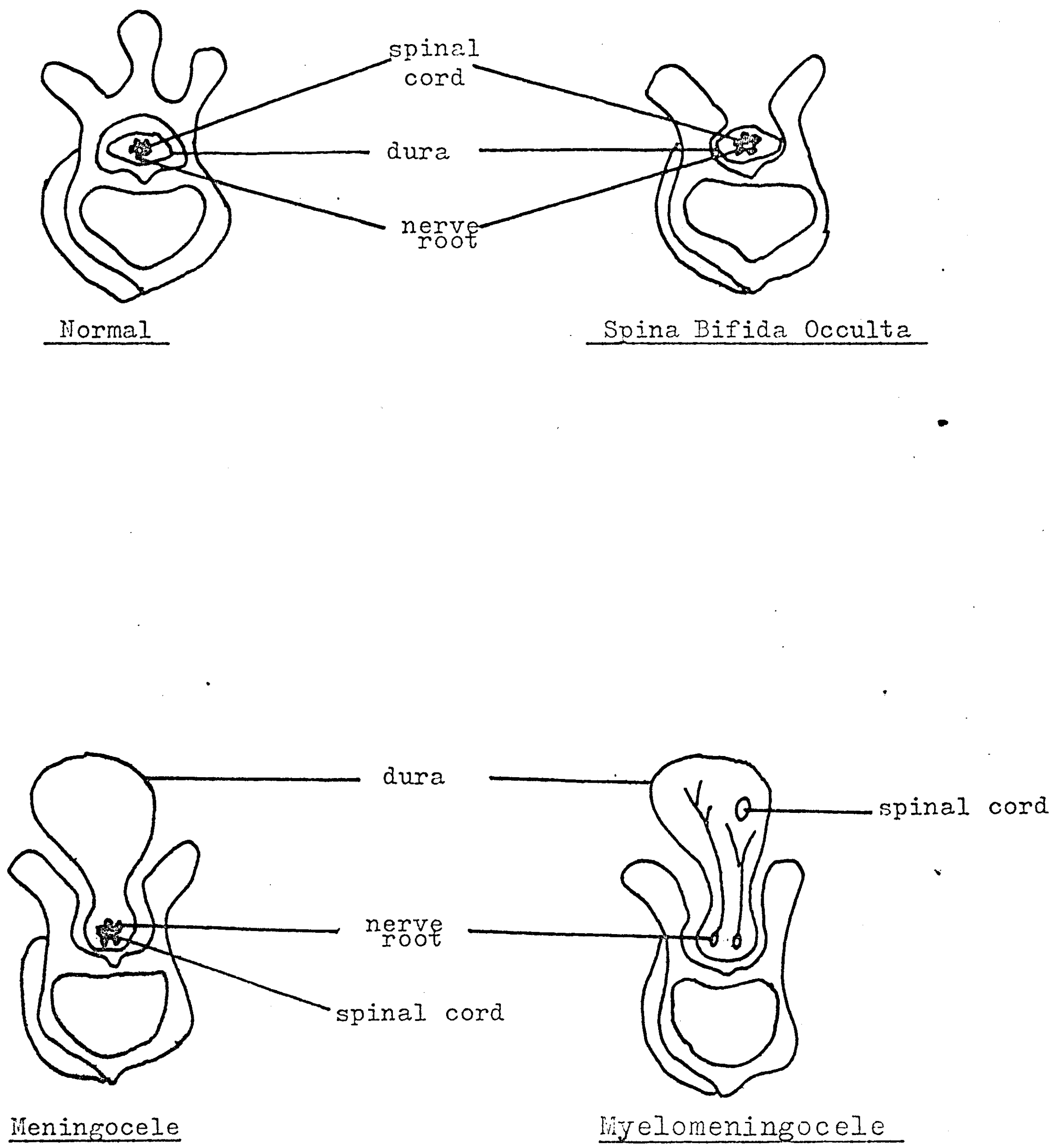


Fig.5. Varieties of Spina Bifida. (Carter and Gold. 1974.)

are of this type whereas Menelaus(1980) in Australia gives the figure as 11%.

Myelomeningocele.

This is the more severe form of Spina Bifida and is very much more common than Meningocele. The vertebrae, meninges and spinal cord are all malformed and as a result the child will suffer from some degree of paralysis to the legs, bladder and bowel. The severity of the handicap depends upon the extent of the damage to the spinal cord and is affected by the level of the lesion and the number of vertebral segments involved. In general, cervical or sacral lesions produce less severe handicaps in survivors than do lumbar or thoracic lesions(Brocklehurst 1976). Menelaus(1980) states that 89% of the surviving children with Spina Bifida are of this type.

Other related neural tube defects.

Other neural tube malformations similar to Spina Bifida can also occur, the main ones being Cranium Bifidum and Anencephaly.

Cranium Bifidum(Encephalocele).

This is a defect in the fusion of the bones of the skull usually at the back of the head, and may result in abnormalities of the underlying brain. Some of the lesions contain only meninges and some contain actual brain tissue but they are all generally referred to as Encephaloceles. The outlook for the child depends upon the extent of the brain abnormality, if any.

Anencephaly.

This is an actual defect of the entire anterior part of the brain with a failure of the formation of the skull and incomplete formation and degeneration of the cerebral cortex. The basal parts of the brain then lie exposed on the surface. Such children are commonly stillborn or die soon after birth(Brocklehurst 1976).

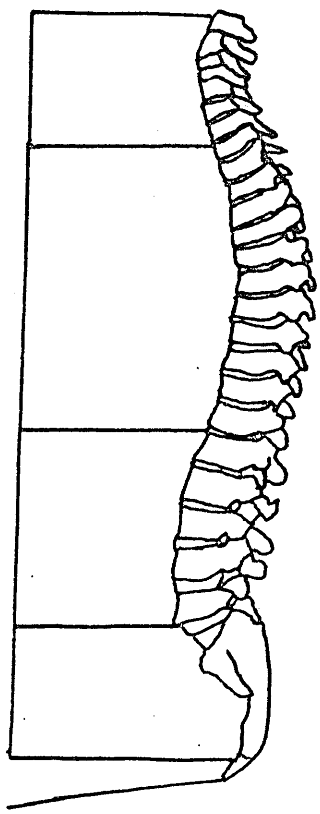
Paralysis and locomotion in Spina Bifida.

Lumbar and particularly thoraco-lumbar lesions are likely to produce quite severe paralysis (Lonton 1977),(Fig.6). Cervical cases are normally meningoceles with little handicap and those with sacral lesions normally have little handicap because fewer nerve roots are involved. The majority of children with myelomeningocele have lesions in the lumbar and lumbar-sacral area because that is the last part of the neural tube to close. Menelaus(1980)found in a sample of 295 patients that 27% had lumbar lesions,42% lumbar-sacral lesions and 21% sacral. In 2% the entire lumbar-sacral region was involved. 92% of the lesions were below the second lumbar vertebra and 42% at the lumbar-sacral junction. Only 1% fell in each of the cervical and thoracic categories and 6% were thoraco-lumbar.

Lonton(1977) found in a group of 347 children that 37% of the lesions were thoraco-lumbar,18% thoraco-lumbar-sacral,10% lumbar and 4% sacral. 30% were lumbar-sacral, only 1% were thoracic and there were no cervical lesions. He noted that his figures did not agree with some previous studies and accounted for this by the fact that his whole group had hydrocephalus whereas children with myelomeningocele but no hydrocephalus tend to have lower lesions. Thus other studies show more children with lower lesions. This is the case in the study by Menelaus which has already been mentioned.

Between one third and a half of the children with lumbar-sacral lesions or lumbar lesions will have total flaccid paralysis of the lower limbs while others will have significant motor problems (Gabriel 1974). Whatever the degree of lower limb paralysis if Hydrocephalus is present this is likely to make independent walking difficult due to problems of balance. If there is intellectual impairment this is also likely to affect walking as the child will have difficulty working out how to use his limbs or walking apparatus. Other associated abnormalities such as scoliosis,kyphosis,hip dislocations or fixed limb deformities of the feet or ankles(arising from muscle imbalance due to disparities in the nerve supply)may also affect walking.

Diagram to show the vertebrae and the level of spinal nerves.



Vertebrae	Spinal nerves
Cervical	Nerves to arms.
Thoracic	Nerves to hips, legs and colon.
Lumbar	Nerves to hips, legs and bladder.
Sacral	Nerves to sphincter muscles of urethra, feet and rectum.
Coccygeal	No nerves.

Fig. 6 .

Brocklehurst(1976) comments that lack of proprioception of the superficial and deep structures in the lower limbs is one of the factors that may result in lack of coordination and balance in efforts to walk. That this is not the only factor is illustrated by the fact that children with congenital hydrocephalus often show delay in walking and difficulties in balance. He suggests that this is due to poor spatial orientation and cerebellar deficiencies. These factors may delay the establishment of walking, even with aids, beyond the age of four years in children who otherwise would seem to have satisfactory lower limb musculature.

Milhorat(1972) states that disturbances in gait and motor function are relatively common in children with Hydrocephalus. Frequently a spastic paraparesis is evident and this may be associated with a milder spastic weakness of the upper extremities. Such findings may be caused by a stretching of the corticospinal fibres around the enlarged lateral ventricles.

Anderson and Spain(1977) quoting Smith(1965) suggest that in locomotor terms four main groups can be distinguished. Firstly the most severely handicapped children are those with lesions at or above the third lumbar vertebra, who are totally paraplegic and will need total support to the lower limbs.

The next group are those with lesions at or below the fourth lumbar vertebra where the children will have paralysis of some of the muscles of the hips and knees as well as paralysis of the feet. They will need support in these areas.

Thirdly are those with lesions at the first and second sacral vertebrae who may have just adequate function at the hips but will need support to the feet.

The least handicapped group have lesions below the third sacral vertebra. Their lower limb function will be normal but they may be incontinent.

In practical terms this means that a large percentage of the first two groups will eventually be wheelchair bound. By the time they reach their teens the effort of trying to drag themselves around with all the braces and calipers that they have to wear ceases to be worth the struggle. Lonton(1977) in the study of 347 children, which has already been mentioned, found the following percentages of each group in wheelchairs. The upper age limit of the children was ten and a half years.

Thoraco-lumbar-sacral	96%
Thoraco-lumbar	87%
Lumbar-sacral	50%
Lumbar	77%
Sacral	0%

This gave a mean for the group of 68% wheelchair bound before they reached their teens. Despite this situation it is generally accepted that an attempt should be made to get these children into a standing position as early as possible in order to give them a normal view of the world and to aid kidney function(Menelaus 1980). He also emphasises that the child's difficulties in locomotion are better understood if those dealing with him appreciate the possible perceptual difficulties and upper limb abnormalities, as well as the fact that they lack sensory information from the paralysed limbs which therefore affects posture and gait.

Hydrocephalus.

According to Anderson and Spain(1977) 80% of the children born with myelomeningocele will also have Hydrocephalus, a condition which can also occur in isolation. Menelaus(1980) gives an overall figure of 72% of such children being affected. 83% of lower thoracic and upper lumbar lesions and only 60% of lower lumbar and sacral lesions were affected. This supports the findings of Milhorat(1972) and Lonton(1979) that Hydrocephalus tends to occur more frequently in the higher lesions.

Hydrocephalus is caused by a blockage in the normal circulation of the cerebro-spinal fluid in the brain, which therefore accumulates under pressure. If untreated the head will grow rapidly because of the pressure inside. The fontanelle, where the bones of the skull join, will be larger than normal because of the increased tension and if the pressure is not reduced will remain open for longer than usual. If left the baby's eyeballs may become depressed, he will develop a marked squint and his face will look small compared to his head. Damage caused by Hydrocephalus and other deformities of the brain associated with Spina Bifida are likely to lead to intellectual deficits in a number of these children. It is worth remembering that the child with Spina Bifida is not simply a paraplegic but may have a number of other problems. Owing to improved surgical techniques developed since 1958 when the Spitz-Holter valve was introduced to control the Hydrocephalus, a greater number of children have survived, many of whom are very badly handicapped. Several different situations can exist regarding Hydrocephalus.

Arrested Hydrocephalus.

Milhorat(1972) describes this as a state of chronic Hydrocephalus in which the pressure of the cerebro-spinal fluid has returned to normal. Children with mild Hydrocephalus which has spontaneously arrested are unlikely to suffer marked adverse effects, but to be certain of this as a diagnosis requires follow up to check that mental and motor development is progressing steadily. According to Milhorat (1972) many children who are said to have arrested Hydrocephalus but are not showing steady intellectual development are in fact suffering from normal pressure Hydrocephalus. Welch(1978) states that progressive symptomatic Hydrocephalus may occur in the face of normal intra-cranial pressure.

Normal Pressure Hydrocephalus.

In this type of Hydrocephalus(Milhorat 1972) the cerebro-spinal fluid pressure has returned to a normal range, but a slight pressure gradient persists between the ventricles and the brain. As a consequence the ventricles gradually enlarge accompanied by a slow but progressive wasting of the white matter of the brain.

This may affect the overall psychomotor development of the child and may be suspected when there seems to be no other explanation of the child's problems(Hammock et al. 1976).

Untreated Hydrocephalus.

Laurence and Coates(1962) followed up a series of 182 cases of untreated Hydrocephalus, three of whom could not be traced.

81 of these cases showed spontaneous arrest, 89 had died and 9 had progressive Hydrocephalus. Of the survivors 73% had an IQ of above 50 and were considered to be educable, with 38% actually falling within the normal range(above 85). They concluded that children with Hydrocephalus were not without hope even when untreated, although there was a poorer prognosis when it was combined with Spina Bifida Cystica. They found that of those who survived to the age of three months the life expectancy into adult life was 26%.

Treated Hydrocephalus.

It seems likely that some damage will have resulted from the Hydrocephalus even when it has been treated. Wallace(1973) suggested that Hydrocephalus, whether treated or not, was associated with a significant increase in abnormal neurological findings in the upper limbs with a significant reduction in adequate mobility. It is likely that the motor control of the lower limbs is affected and balance is poor even in those who have Hydrocephalus in isolation. The corpus callosum is often stretched and thinned(Milhorat 1972). Little research has been done in this area but Miller and Sethi(1971) suggest that this affects the efficiency with which the corpus callosum can transfer information from one hemisphere to the other. Moderate or severe Hydrocephalus can result in some degree of intellectual impairment, which will be considered in more detail later, and squints commonly occur.

The Arnold Chiari Malformation.

This is an abnormality of the cerebellum and other nearby lower brain structures which occurs in association with Myelomeningocele and Hydrocephalus. This is one of the major brain abnormalities known to occur in nearly all of these children(Anderson and Spain 1977).

The malformation consists of:-
(Brocklehurst 1976)

(i) Caudal prolongation of the cerebellar vermis which at its worst bulges right into the fourth ventricle and central canal.

(ii) The fourth ventricle can be displaced into the upper cervical canal and the lower end is often closed off from the central spinal canal.

(iii) The medulla is misplaced into the upper cervical canal and may be kinked dorsally.
(iv) Around the lower end of the brainstem there may be thickening and inflammation of the meninges.
(v) The cerebellum weighs less than usual and there is a dearth of tissue in the central lobes, various cells out of place and a lack of Purkinje cells.

The role of the cerebellum used to be thought of as to modify the timing of movements so that they were effective and smooth but not to initiate them. Evarts et al.(1973) suggest that the cerebellum is probably involved in the planning and initiating of the precise and rapid movements characteristic of the extremities, particularly the arm and hand. The cerebellar vermis is concerned with posture and balance and the only direct route out from the cerebellum for nerve impulses is via the Purkinje cells. These tracts do not directly affect motor neurons but affect other pathways which ultimately affect motor neurons, such as the cortico-spinal and vestibulo-spinal pathways. They are very much connected to the vestibular system which is concerned with balance.
Whereas information to and from the cerebral cortex has to cross to the opposite side of the body, the right side of the cerebellar hemispheres is concerned with the right side of the body.

Cerebellar disorders result in such things as dizziness and poor balance, disturbance of voluntary movements, and errors in direction, force and rate of movements. This latter is described by Mackenzie(1963) as cerebellar ataxia.
Dow(1969) noticed muscle weakness in the arms, delay in starting and stopping movements and tremors in those with cerebellar disorders. It seems likely that this is one of the main causes of upper limb dysfunction in these children and the findings of Wallace(1973) in this respect will be considered in the next section.

Gordon(1972) suggests that the lower brain stem structures which are affected by the Arnold Chiari malformation play a more important part than at first thought in the processing of visual,auditory and other inputs,as well as integrating simultaneous inputs (Ayres,1975).

Upper limb function.

This has already been touched upon as it links up with discussion of Hydrocephalus and the Arnold Chiari malformation.

Wallace(1973) examined the neurological functioning of the upper limbs of 225 unselected children with myelomeningocele who were at least one year old. She found upper limb dysfunction in 156(69%) of them including 122(82%) of those with Hydrocephalus and 34(45%) of those with myelomeningocele but no sign of Hydrocephalus. The predominant disorders were either cerebellar ataxia or mixed cerebellar ataxia and pyramidal tract dysfunction, a view supported by Menelaus (1980).

Minns et al.(1977) quoted these findings in their account of research in this area. They postulated that the poor mobility resulted from the effect of varying degrees of cerebral palsy superimposed on the paralysis due to the spinal lesion. They suggested that manipulative skill in these children is probably depressed due to lack of learning opportunities as they have had to use their hands for support or to push their wheelchair, with other possible causes being cortical trauma from shunt procedures, meningitis and ventriculitis and cervical myelomeningoceles.

31 children of 6-8 years old from the Royal Hospital for Sick Children,Edinburgh were studied along with a control group of 31 children who had been in hospital for minor surgery such as tonsillectomy. A neurological assessment and a functional assessment(daily living skills and manipulative tasks) were used.

51.6% of the Spina Bifida group had lesions above the 2nd lumbar vertebra and were severely paralysed. 7 of the children were meningoceles and 24 myelomeningoceles. Although this was only a small study it was concluded that not only do Spina Bifida children have functional difficulties with their upper limbs but that these might not be picked up on routine neurological testing meaning that the child might be in school with unrecognised difficulties. They relate the difficulties in the upper limbs to Hydrocephalus and the presence of a shunt and identify them in terms of 'hard' neurological signs of such things as ataxia and 'soft' signs of delayed maturation.They suspect that some of the maturational signs persist throughout life.

Lonton(1976) studied handedness in a group of approximately 200 Spina Bifida children compared with a control group. In the Spina Bifida group there were significantly more left and mixed handers although in both groups mixed handedness declined between the ages of five and six. He found mixed handers to have a significantly lower verbal I Q on the WISC,lower reading attainment and the upper limit of the lesion tended to be in the thoracic region. This caused him to suggest that handedness may not only be determined by cortical factors but may be influenced by motor or sensory dysfunction due to assymetrical lesion of the thoracic cord.

Spain(G.L.C. study 1970s) found an abnormally low proportion of pure right handers in the Spina Bifida group and an abnormally high proportion of mixed and left handers. Even children without shunts fell into this category,but most of them had arrested Hydrocephalus. Anderson(1975) agreed with these findings. The reasons for the failure to establish hand preference are by no means clear and Spain suggests that damage to the central nervous system by Hydrocephalus could play a part, as could neurological immaturity.It is also possible that the corpus callosum does not function efficiently thus preventing the ready transfer of information from one hemisphere to the other thus causing lack of specialisation of hemispheric function (Gadsdon et al.1978). Alternatively it may be because they sit late,use one hand as a prop and get little early practice in manual tasks.This idea linked with that of neurological immaturity would fit in well with Lonton's findings that mixed handedness decreases as they get older. Possibly they are just several years behind normal children in this developmental stage. Encouraging the

child to use a preferred hand consistently may well help this development.
Variend and Emery(1973) found various characteristics of the cerebellum in the Arnold Chiari malformation which accord with those of Brocklehurst(1976) already mentioned. In addition they comment that with the effects of cerebellar atrophy and frontal lobe damage caused by Hydrocephalus it is not surprising that Spina Bifida patients have ataxia in the upper limbs.
It should by now be clear that in considering the educational problems of these children the likelihood of upper limb dysfunction must not be forgotten. This is especially necessary where integration of children into normal school is considered as a teacher with no experience of such children is unlikely to be aware of the sort of problems to expect.

CHAPTER ONE. SPINA BIFIDA.

Part 2. Treatment, causation and prevention of Spina Bifida.

Treatment, Causation and Prevention of Spina Bifida and Hydrocephalus.

Selective non-treatment.

The modern trend is for selective non-treatment at birth where it is very obvious that at best the child will grow up to be very severely physically and mentally handicapped. This combined with the falling birthrate and screening procedures means that there will be fewer new children with the condition reaching school age. Obviously the criteria for selection are very important and Lonton(1977) suggests that from knowing the level of the lesion at birth a set of predictions can be made about the likely outcome for the child. Other criteria have also been used and are frequently under consideration by those who have to apply them, in order to avoid not treating a child with a good prognosis.

At the present time the 'bulge' of children who were operated on and kept alive at all costs is still going through school and in need of education. It is possible that the present trend will be reversed to some extent as there is a lot of controversy over the selective non-treatment situation.

Two important court cases were in the news in 1981 concerning this and related matters.

In September the case was concluded against Dr. Jolly resulting from the death of a Spina Bifida boy at Charing Cross Hospital in 1979. The case was reported to the police by 'Life' organisation which also campaigns against abortions. The Director of Public Prosecutions announced that no action would be taken against Dr.Jolly. 'Life' maintained that in some cases handicapped babies were sedated so that they did not demand food and eventually died. Dr.John Harvard, Secretary of the British Medical Association welcomed the decision of the D.P.P. and stated:-

> Recent advances in medicine have created serious clinical and ethical dilemmas for doctors, particularly in the case of severe abnormality in newborn children.

This is a view shared by Professor Lorber, a paediatrician, who at one time agreed with an heroic policy of operating on all children, but over the ensuing years when he came to see the results of his labours changed his opinions. In 1971 he produced an analysis of the results of treatment on 524 unselected cases of myelomeningocele with special reference to possible selection for treatment. He defined five classes of handicap with the following percentage of survivors in his 1959-63 series.

1) No handicap. 3%.
2) Moderate handicap. Ambulant but may have motor weakness, be incontinent and have well controlled Hydrocephalus. 15%.
3) Severe handicap. I Q more than 80. Poor mobility, with 50% of the group in wheelchairs and others needing walking aids. Incontinent with frequent urinary infections. 49%.
4) Severe handicap. I Q of 61-79. Similar physical disabilities to category 3. 21%.
5) Extreme handicap. I Q below 60. Apart from all the physical handicaps already mentioned this group are also prone to fits and have poor sight or blindness. 12%.

Thus 82% of the children fell into the severely handicapped category or worse with 33% of them intellectually retarded as well.

Of these children 4 without handicaps and 50 others were in normal school, 69 were in schools for the physically handicapped, 1 was in an E.S.N. school, 1 having home tuition and 9 having no formal education at all.

The findings based on his next series of children were very similar.

He summed up his paper by stating that in the absence of treatment most infants born with myelomeningocele die early in infancy and it is inferred that almost all the more severe cases do so. Improved methods of treatment rigorously applied have led to an increased survival rate but the large majority of survivors have major physical defects and a lot are also mentally retarded.

In this study Lorber found that the infants who fared worst were those with extensive paralysis at birth, those with a head circumference exceeding the 90th percentile by 2mms.or more and those born with gross kyphosis or other major associated congenital defect. Lorber claims that his data show that selection for treatment can be made, and argued that on humanitarian grounds this should be done, However Zachary of Sheffield had different view and was quoted by The Daily Telegraph(6.11.81.) as saying:-

> Doctors have a clear duty to save the lives of all babies born handicapped even though they know they will grow up physically handicapped or mentally retarded.

He estimated that 300-400 handicapped babies a year were being illegally killed by being drugged so that they did not want to feed and therefore died. This supports the comments made by 'Life' organisation on this subject. This view was opposed by Dr. Garrow of Wycombe General Hospital who said that it was often a loving thing to let a handicapped baby die. He also said that he had asked many severely handicapped adults whether they thought a baby with similar handicaps should be enabled to survive at birth and in most cases the answer was in the negative.

In October 1981 Dr. Leonard Arthur was in court for allowing a Mongol baby which had been rejected by its parents, to die. Again it was alleged that drugs were given which lead to the development of pneumonia and subsequent death. The charge first brought was one of murder which was later reduced to attempted murder. As the case progressed various pieces of information given by the prosecution were found to be incorrect and Dr.Arthur was found not guilty.

This of course started even more controversy as both the Catholic and Anglican churches made statements on the subject and 'Life' were completely dissatisfied with the verdict.

Earlier in the year a baby(Mongol) with complications had been taken away from its parents when they refused permission for an operation as they thought it better for the child to die.

These three cases give some idea of the extent of the problem of selective non-treatment and there is obviously no clear cut answer which will satisfy everyone. Even the medical profession are very much divided on the subject.If those opposed to the present situation do win the day it should not result in as many Spina Bifida children reaching school age as in the past as screening procedures can now be used in early pregnancy and abortions carried out if the parents so wish. This is another controversial topic. Primary prevention,which is discussed later is the only truly satisfactory solution to the problem as it does not involve such difficult ethical problems.

Amniocentesis and screening for neural tube defects.
(Black Report 1979)
Amniocentesis is used for screening purposes and is fairly reliable but not foolproof.Four out of five of the open neural tube lesions will be identified by this method. In amniocentesis a sample of amniotic fluid is taken at 16-18 weeks after conception. Raised levels of alpha-feto-protein occur in the fluid at this time in Anencephaly and Myelomeningocele which are open neural tube defects. Encephaloceles and Meningoceles cannot be shown by this method and certain other situations such as multiple pregnancies show raised A F P levels so must obviously be identified early on in investigations. This sort of screening is normally carried out in association with ultrasound which is completely harmless, and can enable accurate dating of the pregnancy,exclude multiple pregnancies and in some cases confirm the presence of neural tube defects.
Amniocentesis does carry a slight risk of precipitating a miscarriage and 1-1.5% of the cases tested might be at risk. It is suggested that a number of the mothers tested may well have had miscarriages anyway as in a sample group in Bolton 7% of the mothers with high blood serum A F P miscarried before amniocentesis could be carried out. It is possible to measure A F P levels in the mothers serum between the 16th and 25th weeks of pregnancy as a general screening method which is completely harmless and then follow this up with amniocentesis and ultrasound if required.
If the blood test or amniocentesis is carried out too early it will not pick out an affected child and if left too late it will not be safe for an abortion to take place.

The Black report summarises the natural history of neural tube defects based on 1975 data, before a screening and termination policy was in practice. They estimated that in a year in England and Wales nearly 4000 conceptions will have neural tube defects. 2100 of these will abort spontaneously before 28 weeks of pregnancy and 990 will be stillborn leaving 1000 affected live births. About 540 of these will die in the first month, 125 in the remainder of the first year and 46 between the ages of 1 and 5. Of the 289 survivors at age 5, 43 will have no handicap, 62 will have moderate handicaps and 184 severe handicaps with 49 of the latter group also suffering mental retardation. They suggest that 75% of mothers would take up the option of screening and that as a result 1656 neural tube defect births could be averted in a year. Of these 419 would have aborted spontaneously, 661 would have been stillborn, 329 would have died in the neonatal period, 75 in the remainder of the first year and 28 between the ages 1 and 5. Of the 144 who would have survived to age 5, 107 would have been severely handicapped and 37 moderately handicapped. They emphasised that the whole subject needed more detailed statistical study now that it was becoming more widespread even though by 1979 the initial A F P blood serum screening was only available as routine in 46% of the areas of England and Wales.

In Edinburgh, where research has been taking place (Moussa & Scobie 1980), graphs were plotted showing 103 Spina Bifida cases admitted over a ten year period from 1969-79, against the years of admission and the amniocentesis figures and birth rates for the same years. It shows that the number of Spina Bifida admissions has progressively fallen and this they feel is in part due to the fall in the birthrate but also due to the increased antenatal diagnosis and the abortions that have resulted.

The first major study (Hibbard 1981) into mass screening for Spina Bifida has shown that a 72% detection rate can be achieved. This was the finding of the Welsh National School of Medicine based on a three year study in mid Glamorgan which has always been one of the high incidence areas for Spina Bifida, with one birth in every 200 affected.

Nearly 16,000 pregnancies were studied and 11,000 women had serum A F P tests. 686 women had amniocentesis. In the screened population there were 61 neural tube defects of which 44 were detected. Thus these mothers could choose to terminate the pregnancy. 28% of the mothers attended after the 19th week of pregnancy which is too late for testing. Professor Hibbard, who was in charge of this research, suggested that getting mothers to the clinics early in pregnancy is the biggest factor in improving the results.

The Treatment of Spina Bifida and Hydrocephalus.

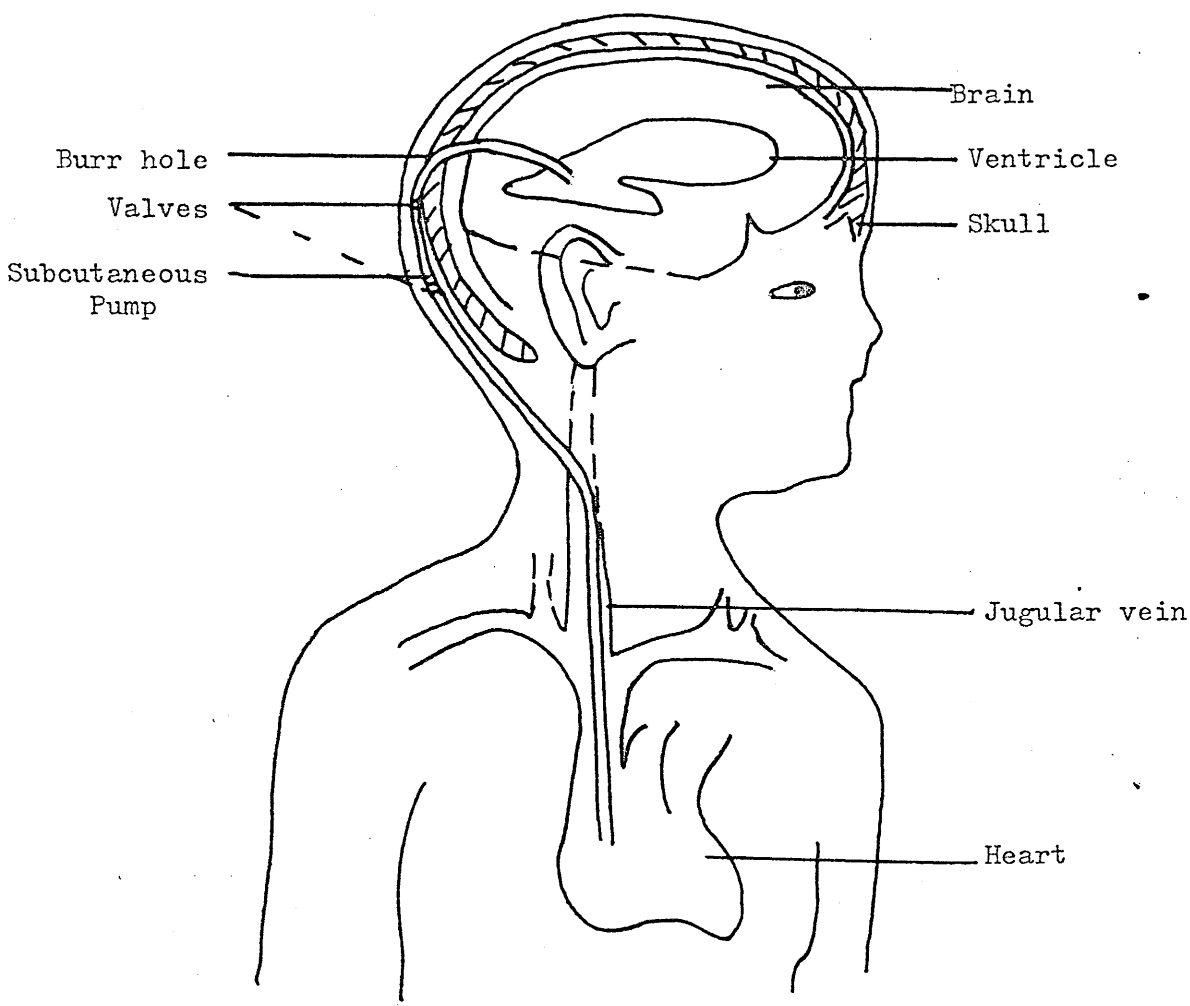
When treatment does take place, shortly after birth and generally within the first 24 hours, the lump on the back is removed and the lesion is covered with skin. This is necessary to reduce the danger of infection and to prevent further physical damage to the cord.

In those with Hydrocephalus at two or three weeks(or sometimes earlier) a shunt is inserted just beneath the skin behind the ear and is connected to the ventricles of the brain at one end and the right receiving chamber of the heart at the other (Fig.7), Unfortunately these surgical procedures can result in further injury to the child. When the shunt is inserted the ventricles of the brain return to a more or less normal size fairly rapidly which can in effect result in the brain caving in and impinging on the end of the catheter thus causing a recurrence of the Hydrocephalus. Gruber(1980) reports that Hydrocephalic patients suffering from over-drainage of the cerebro-spinal fluid show similar symptoms to those suffering from raised intra-cranial pressure. He suggests that it is possible to prevent this happening and has successfully experimented with a device that can be inserted in the shunt to prevent what he refers to as unnecessary shunt problems.

There is also the problem of the shunt ceasing to work, becoming blocked or becoming infected. One school of thought suggests that many children as they grow older become independent of the shunt because the Hydrocephalus becomes arrested. Lorber (1981)reports the removal of shunts in children found to no longer need them. The shunt is first tied off and the situation monitored before proceeding further.

The use of isosorbide in the early stages of Hydroceph-alus is considered by Lorber(1972) as being of value to give time to see if spontaneous arrest will take place and obviate the need for surgery. Lorber reports that the results of a clinical trial using isosorbide suggest that the proportion of children avoiding surgery could be increased, particularly in moderate Hydrocephalus among children with Spina Bifida. Although severe cases of congenital Hydrocephalus are unlikely to respond well,

Fig.7. Shunt for relieving excessive ventricular pressure in the brain. (Field 1970a.)



a few weeks postponement of surgery may be gained and this is important where the patient is very young or not fit for operation. In Lorber's trial shunt operations were carried out if there was rapid progression of the Hydrocephalus or if it had not arrested by the end of the treatment period. Hayden and Shurtleff(1972) had also found isosorbide to have temporary favourable clinical effects either in the reduction of ventricular fluid pressure, arrest of abnormal head growth or decrease in CSF leakage. Hemmer and Bohm(1976) in an article entitled 'Once a shunt, always a shunt', point out that it is only in rare cases that removal of a shunt can take place successfully. They had removed shunts from 26 children with communicating Hydrocephalus of whom 17 continued to be compensated, and from 14 children with Hydrocephalus associated with Myelomeningocele all of whom remained compensated. These 40 children were from a total population of 444. They stress that true compensation can only be proven by continuous measurement of ventricular fluid pressure over periods of several hours or at intervals of days or weeks. They discuss four cases where decompensation occurred, two having fatal results, and suggest that it is advisable to leave the shunt in as it may be needed intermittently. There is certainly no guarantee in children with Hydrocephalus, with or without shunts, that the condition will remain stable.

Hospitalisation.

In addition to the primary surgery required for Spina Bifida and Hydrocephalus and possibly secondary surgery for Hydrocephalus these children may require a number of orthopaedic operations and operations on the urinary tract. This can result in a large number of hospital admissions some of which are lengthy.

Freeston(1971), in Sheffield, studied children aged four years and found that the average number of hospital admissions for children with Spina Bifida was six. She quotes that in a national population survey taken in 1958 only 20% of normal children of five years of age had ever been in hospital. Tew and Laurence(1976) found that up to the age of nine years 43 actively treated cases of Myelomeningocele had had an average stay of 28 weeks in hospital, with 20%

of them having spent in total between one and two years in hospital.The average number of operations was six. After school age the number of hospital admissions declined. Girls spent longer in hospital than boys and those with IQs of less than 80 on the WISC spent twice as long in hospital compared to intellectually competitive children, probably because of the Hydrocephalus and greater physical handicaps. They also used the Bristol Social Adjustment Guide with these children and found that admissions to hospital had little emotional effect, probably due to familiarity.
The enforced passivity whilst the child is in hospital may become habitual and continue even after they get home, thus reducing still further their chances of interacting with the environment. Soare and Raimondi(1977) found that children with the least perceptual-motor difficulties were those who had had the least time in hospital during the first five years of life(P=0.01).

Incidence and Causation.

Compared with other countries Britain is a high incidence area and even within Britain there is considerable variation from region to region. Ulster, Western Scotland and South Wales are the worst areas and moving towards the South and East the incidence drops. In 1977 the incidence ranged from 3.9 per 1000 live births in Wales to 2.6 per 1000 live births in East Anglia(Black 1979). Overall 2 per 1000 live births in this country are anencephaly and 2.4 per 1000 are Spina Bifida(Carter 1969). In both the North and the South of Ireland the incidence is as high or higher than in Wales or Scotland.
Much research has been done to try and find the cause of neural tube defects as this is obviously necessary in order to prevent further cases appearing.
Lonton(1980) found that Spina Bifida is slightly but statistically significantly more common in the lower social groups. Neonatal Hydrocephalus was found to be more severe in these groups and it was also suggested that they had higher and larger lesions. These findings may well be statistically correct as Lonton

studied approximately 1000 patients. It is worth remembering his findings when considering the work that has been done on diet as a likely cause of Spina Bifida as there is more of a tendency for the lower social classes to eat an inadequate diet (Smithells 1980).
It is generally considered that there is a genetic predisposition which is triggered off by some environmental factor to cause Spina Bifida. All sorts of such factors have been studied. In genetic terms sex,(there is a 1.3/1 ratio of girls to boys among Spina Bifida survivors) ethnic variations and heredity have been considered. On the environmental side water, social class, seasonal trends, maternal age and diet have all been studied.
One of the aspects of diet which was intensively studied in the early 1970s was the potato.
Renwick(1972) mentioned that a correlation in geographical space had been found in published material between the average severity of late blight attack of potatoes and the incidence of Anencephaly and Spina Bifida in man.
A correlation is also found between the incidence of these malformations and the blight severity in the year prior to which the teratogenic insult occurred. He suggested that absorption of the harmful substance is probably by ingestion but could be inhaled during scraping or cooking.
Masterson(1974) disagreed with Renwick's findings. He postulated that if potatoes were a cause of Spina Bifida and Anencephaly the incidence would have been reduced during the mid 19th century potato famine in Ireland. This was not found to be the case.
Knox(1972) also investigated Anencephaly and dietary intakes. He found negative(protective) associations with cheese, meat and apples, but positive associations with bread, cereals, ice-cream, canned peas and a variety of cured and cooked meats. He considered magnesium salts in canned peas and nitrates and nitrites in cured meats to be possible causes of the problem, and found that both canned peas and cured meats have geographical distributions of consumption which are compatible with regional variations in the incidence of Hydrocephalus.
Up to this stage although correlations had been found little could be done about the situation as there were

too many variables involved. However this has led to the present work on diet which involves supplementing the diet of 'at risk' mothers in an attempt at prevention.

Primary Prevention.

Recent research has centred round the diet of the pregnant mothers,not in terms of what they are eating but in terms of what is lacking in their diet both before and during pregnancy. Smithells(1980) stated that there was a social class gradient in the incidence of Spina Bifida and that this could suggest that nutritional factors were involved. Groups of mothers were selected from those referred to paediatric departments in Leeds,London,Belfast,Chester and Manchester who had had previous children with neural tube defects. All who fell into that category were invited to take part and a control group was made up of those who declined to take part or were already pregnant when referred. Those who took part took periconceptional vitamin supplementation of multi-vitamins and iron from at least 28 days before conception to at least the date of the second missed period (i.e. after the time of neural tube closure). Of the fully supplemented mothers only 1 of 178 infants had a neural tube defect (0.6%) compared with 13 of 260 of unsupplemented mothers (5%). Both groups were offered amniocentesis and all those with raised A.F.P. levels had their pregnancies terminated. This included 1 supplemented mother and 11 unsupplemented mothers. Smithells felt that the most likely reason for the favourable result was the vitamin supplementation. James et al.(1980) found that mothers who had previously produced a child with a neural tube defect had had a poorer diet during pregnancy than their sisters who had produced normal children and a far poorer diet than that normally eaten by women from social classes 1 and 2. Although earlier research had tended to discount the idea that the incidence of Spina Bifida varied between social classes Lonton(1980) had found a connection and this is supported by both Smithells and James's findings. James gave counselling to the mothers resulting in an improved diet which was supplemented with folic acid tablets. The incidence of children born with neural tube

defects decreased following this treatment.
Sellar(1981) talks about the research carried out by Smithells and comments upon the findings of James on folic acid supplementation. She had carried out experiments on mice and found that in a strain of mice genetically predisposed to Spina Bifida the incidence could be increased by giving Vitamin A eight days after conception but decreased by giving it nine days after. She comments that this critical timing would be spread over a longer period in humans. She found that folic acid had no effect at all.
It does now appear that primary prevention is something that may be feasible in the near future, but as things stand at present new cases are still appearing and a consideration of the physical and mental problems of these children, relating to their educational needs is very necessary. Sklayne(1981) has found, as would be expected, that since selection the problems of these children have decreased because it is the less severely handicapped ones who survive.

Summary of Chapter 1.

A brief account has been given of the incidence, types and treatment of Spina Bifida and related Hydrocephalus, related to the overall development of the central nervous system. It seems likely that this abnormality is present by the 28th day of foetal life and is caused by environmental factors triggering off a genetic predisposition to develop in this way.

Many of these children will be of the more severe type (myelomeningocele) and 80% of these will also have Hydrocephalus and related brain abnormalities. The majority of such children will have paralysis of the lower limbs, neurological abnormalities of the upper limbs and will be doubly incontinent.

The subjects of selective non-treatment, screening for neural tube defects and primary prevention are also considered. All three can reduce the number of cases reaching school age but only prevention is a satisfactory answer to the problem. Present research on periconceptional vitamin supplementation seems to hold out hope that in many cases prevention may be possible.

These children as a group present a problem in educational terms, even within a special school, due to the range and multiplicity of their handicaps. A number of points raised in this chapter will be mentioned again later with regard to their effects on learning. Such factors are physical handicap and mobility, brain damage and hospitalisation.

CHAPTER TWO. NEUROLOGICAL CONSIDERATIONS RELEVANT TO A STUDY OF THE EDUCATIONAL PROBLEMS OF CHILDREN WITH MYELOMENINGOCELE.

<u>Neurological considerations relevant to a study of the educational problems of children with myelomeningocele.</u>

It would be possible to consider all the possible defects in the brain associated with Spina Bifida and Hydrocephalus and link these specifically with the functional deficits shown by these children. This sort of simple cause-effect relationship does not really stand up to very close analysis due to the interconnectedness of the various parts of the brain and the complex way in which they interact to perform any task. Luria (1973) warns that the idea that a particular symptom will reflect a particular lesion is generally unfounded. Mental activity is a complex functional system which may involve widely different parts of the brain. He also points out that lesions have different effects at different ages dependent upon whether a skill has already developed or whether development itself is affected. Equipotentiality of the hemispheres, plasticity of the brain in early childhood and whole brain processes are terms used nowadays in connection with brain function more frequently than rigid ideas about localisation of function. However it is useful to consider some of the ideas on the lateralisation of brain function as they serve to show the confusion that exists in this area. With the considerable amount of brain damage present in some of the children under consideration it is obvious that their problems will be far reaching. Any ideas that can help in an understanding of these problems are of value.
Granit (1977) says,

> This is the glorious climax of evolution, to have created a purposive brain with an incredible degree of adaptability as yet by no means fully explored.

It would be unrealistic to consider the brain damage in Spina Bifida children in isolation, and consideration will be given later to all the environmental factors which play a part in the development of the child from a functional point of view.

DIAGRAMS TO SHOW THE PARTS OF THE BRAIN REFERRED TO IN THE TEXT.

Diagram to show the main parts of the brain.

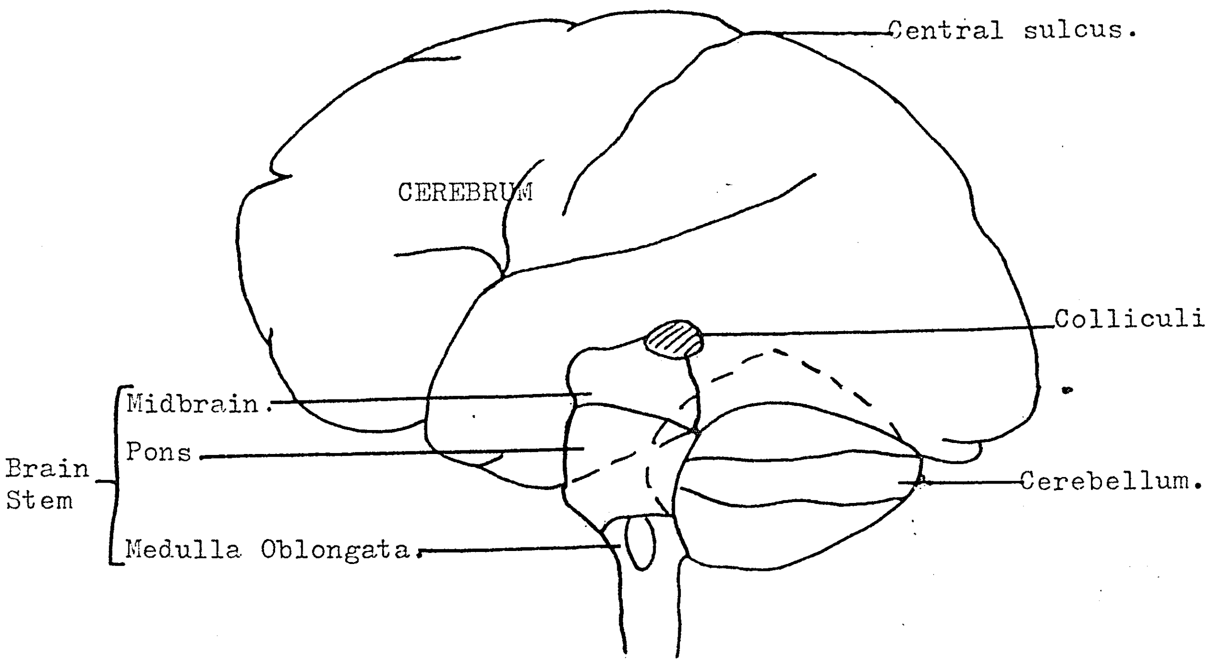


Figure 8.

Diagram to show the lobes of the brain.

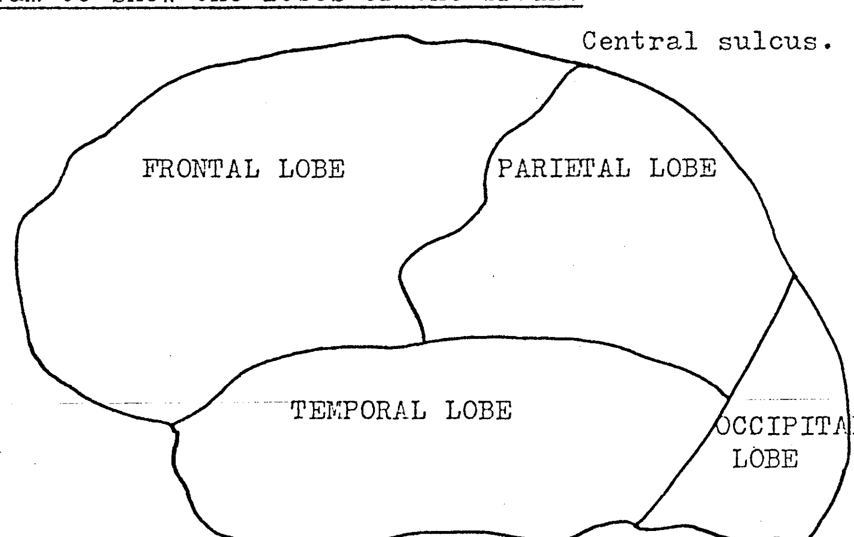


Figure 9.

Parts of the brain shown in a median section (simplified)

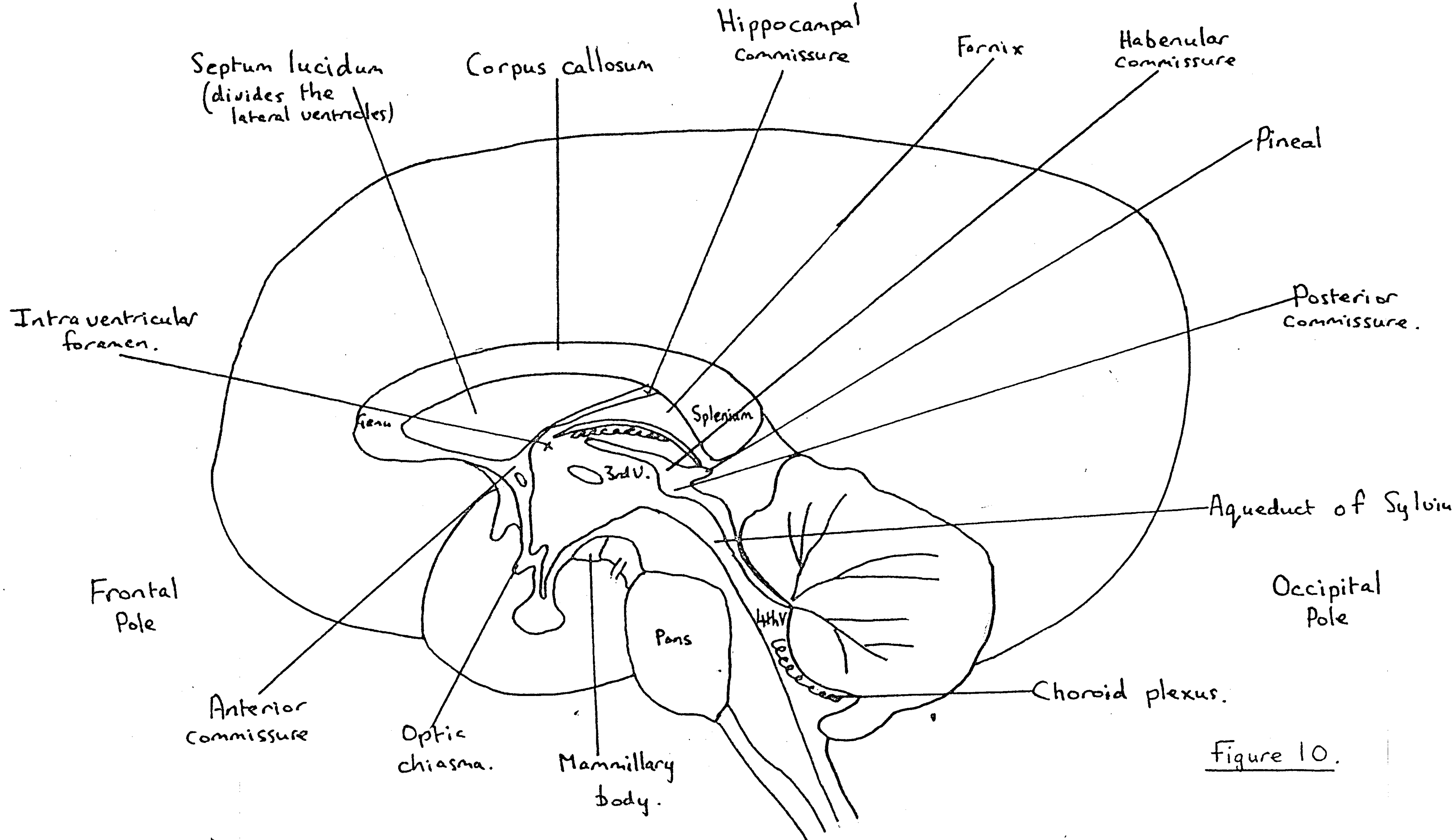


Figure 10.

The inside of the right hemisphere (from Brierley 1976)

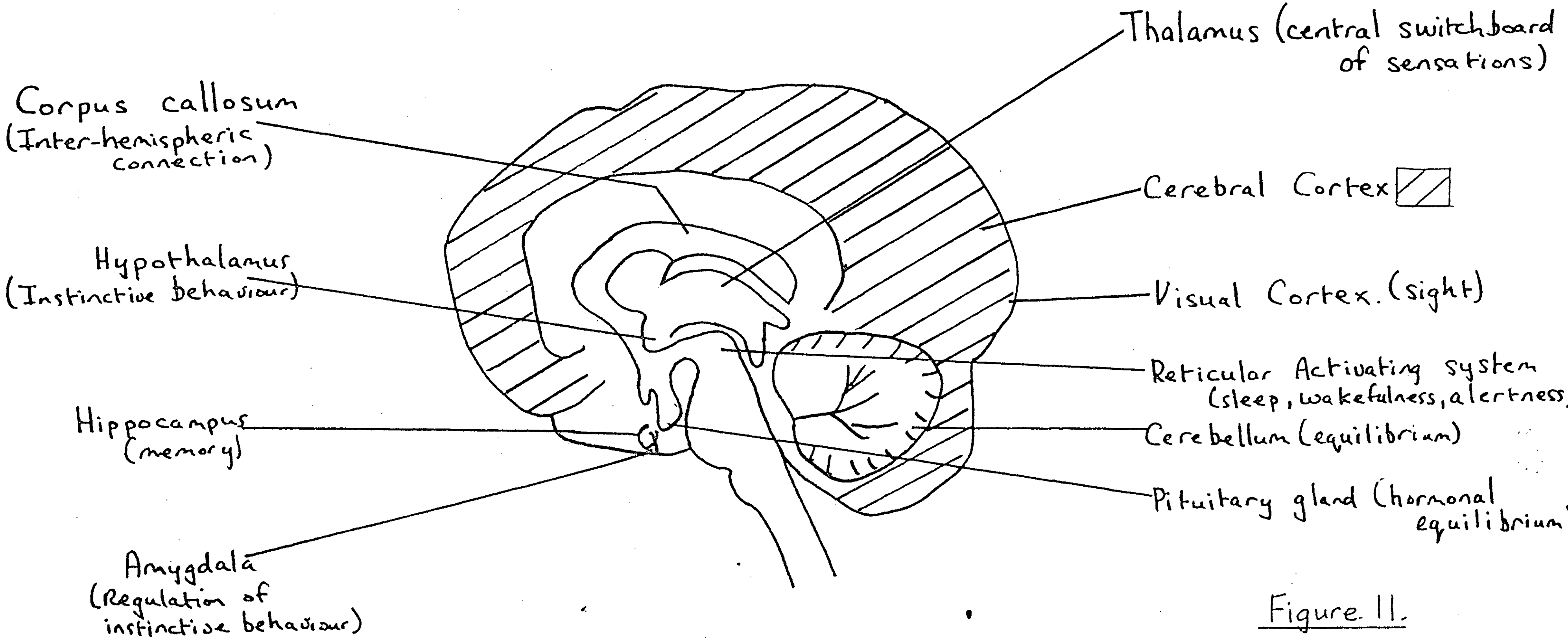


Figure 11.

The outside of the left hemisphere (from Brierley 1976)

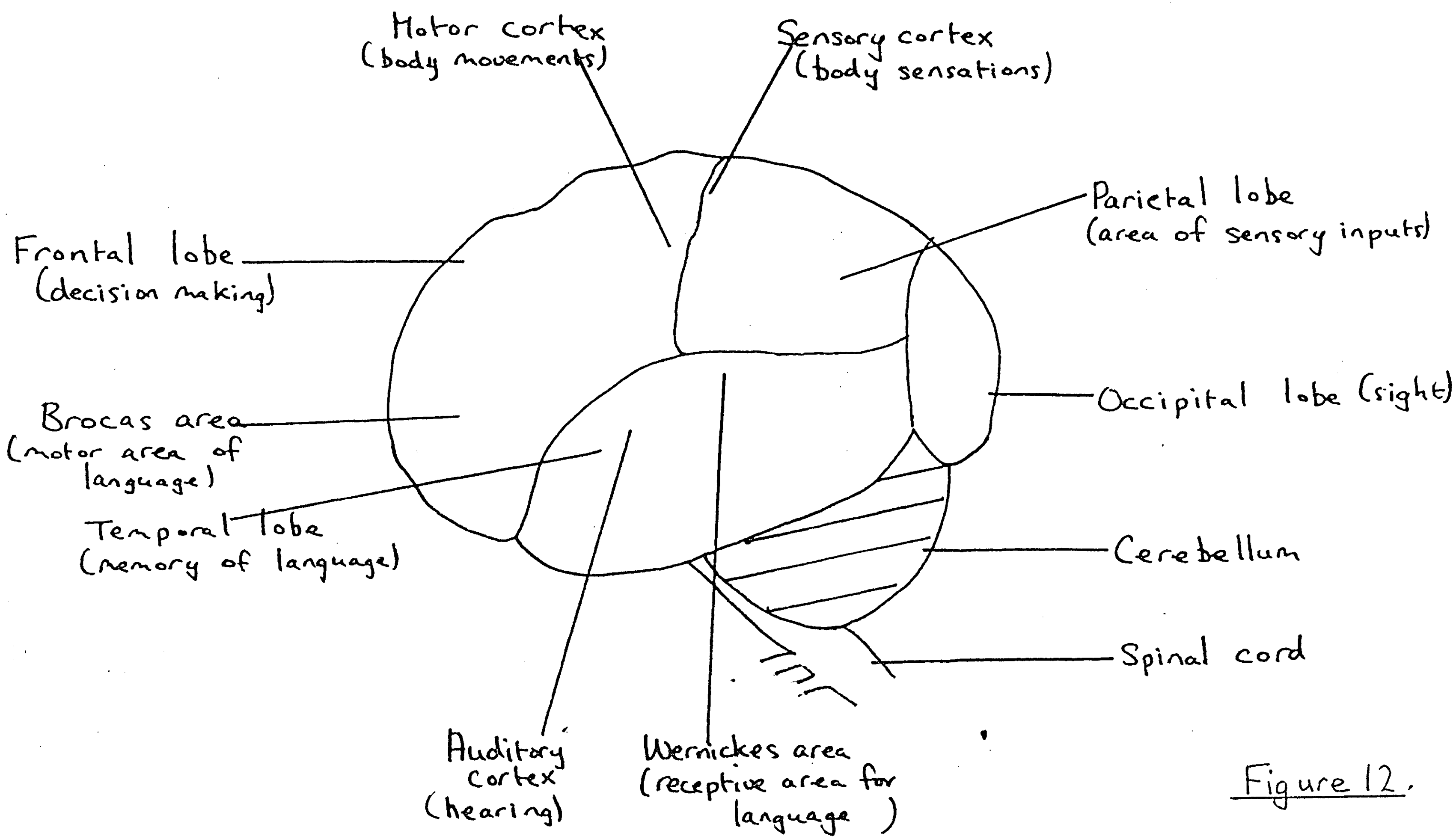


Figure 12.

CHAPTER TWO. NEUROLOGICAL CONSIDERATIONS.

Part 1. An overview of ideas on the lateralisation of brain function.

1) An overview of ideas on the lateralisation of brain function.

There is a great deal of agreement on lateralisation of brain function to the extent that the major hemisphere, generally the left, is considered to be concerned with speech and related activities, whilst the right hemisphere, which is generally the minor one is considered to be involved with visuo-spatial activities.All this can be reversed in some people. Most writers on this subject make only this simple division but some take the matter further and localise activities more. It is interesting to start by considering the ideas of Luria(1970) because some of what he says is at variance with the commonly accepted views. He claimed that a left parietal lobe lesion affected the ability to grasp spatial relations and therefore affects orientation in space, computation and dealing with the complexities of grammar logic. He points out that such behaviour processes that seem unrelated may in fact be related through dependence on a particular brain factor.

Corballis and Beale (1976) quote Luria as claiming that one of his patients with a right parietal lobe lesion showed spatial problems and drew a completely reversed map of Russia. They explain this by saying that damage to the right hemisphere may result in reversed spatial information stored in the other hemisphere being released. By now it should already be apparent that it is difficult to generalise from these sorts of findings.

Eccles(1973) is one person who lays down definate areas of each hemisphere with particular responsibilities and clearly distinguishes between left and right as follows:-
(from Sperry 1965)

Right hemisphere.
No liaison to consciousness.
Almost non verbal, musical.
Pictorial and pattern sense.
Synthetic.
Holistic.
Geometrical and spatial.

Left hemisphere.
Liaison to consciousness.
Verbal.
Ideational.
Analytic.
Sequential. Arithmetical and computerlike.

Milner (1962) had similar views when she found that right temporal lobe and right parietal-occipital lesions impaired visual perception and visual learning including spatial perception. Geffen (1971) found that non-verbal stimuli, such as faces, were processed faster when presented in the left visual field (i.e. to the right hemisphere), whereas stimuli which were verbally encoded and required an identificatory response were processed faster when presented in the right visual field. She concluded that the differences could be caused by the time it took information to cross from one cerebral hemisphere to the other, or by the specialisation of each hemisphere for different functions, or to a combination of both.

Kimura (1973) is another person who claims to have found experimentally that the hemispheres have different functions, with the right being for visual and tactual spatial discrimination, depth perception, location of objects in space and auditory perception of non speech sounds. In fact she suggests that it is the right hemisphere which makes the primary analysis of information about the environment, apart from speech, and then if a verbal response is required the other hemisphere is involved. Once again the right parieto-occipital area is suggested as dealing with spatial relations and the temporal lobe with melodic patterns.The left hemisphere is seen as being specialised for skilled motor acts including speech and the identification of verbal conceptual forms, and is involved in auditory perception of speech sounds and the recognition of visually presented material. The left hemisphere is usually dominant for speech by the age of four, with girls ahead of boys in the development of speech perception.

Luria(1973) detailed the responsibilities of the different lobes of the brain and it is worth looking at a summary of his ideas.

Occipital lobes.

This is the visual cortex and plays a crucial role in the provision of a higher level of processing and storing of visual information. Lesions of the left temporal occipital region cause a disturbance of recognition of letters and reading but right hemisphere damage affects direct visual perception.

Temporal lobes.

This area is concerned with auditory perception with speech being processed and produced by the left hemisphere.

Parietal lobes.

This region lies at the boundary between the cortical zones for visual, auditory, vestibular, cutaneous, and proprioceptive sensations. It analyses the information simultaneously. Arithmetical operations are dependent upon this type of synthesis and disturbances in the left parieto-occipital area affect this. The columnar nature of multi-digit numbers and the fact that their position determines their value brings a strong spatial operational element into this. Equivalent right hemisphere lesions cause disturbances of body schema and orientation in space. He found in patients with right side lesions, despite the profound disturbance of their self perception and self evaluation, that the verbal logical process still existed and led to a characteristic overdevelopment of speech, to verbosity which bore the character of empty reasoning, and which masked their true defects. With this type of lesion the subject can see an object clearly but cannot relate it to personal experience and thus assesses its meaning on the basis of irrelevant associations.

Frontal lobes.

This is the area which regulates cortical tone and thus the level of vigilance and voluntary attention. Lesions result in distractibility, apathy and lack of planning. Actions required by a spoken command are not retained by the patient who may get part of the way and then forget what he is doing. He may remember the command but it no longer controls his actions. Lesions affect active perception and particularly cause figure ground problems as eye fixation is difficult.

Whilst remembering Luria's warning about ascribing certain symptoms to certain lesions the comment needs to be made that problems shown by children with Spina Bifida could suggest damage in several lobes of the brain rather than in one specific area.

On July 14th 1978 a B.B.C. Horizon programme showed how right hemisphere strokes often cause perceptual problems;

a man was shown who had no outward sign of disability but who tried to put on a cardigan back to front and write a cheque upside down.This corresponds to the patient of Luria who drew a reversed map of Russia. An example was also shown of a child who had a damaged left hemisphere where the speech function had been taken over by the right. This serves to illustrate the plasticity of the young brain.

Equipotentiality of the hemispheres.

This latter point leads into another group of writers on laterality who think that there may be a considerable degree of equipotentiality of the hemispheres, especially with regard to language and in the early years.

Corballis and Beale(1976) go along with the generally accepted ideas on the lateralisation of brain function but suggest that because the left hemisphere is specialised for verbal processes it is deficient in many perceptual and cognitive functions. They suggest that it is possible that the left hemisphere develops slightly earlier than the right so that language which starts to develop earlier develops in that hemisphere. While the left hemisphere is becoming dominant in this sphere the right develops its specialism for non-verbal processing. Maturation of the two sides of the brain may proceed in cycles, with the left first and the right periodically catching up. Any skill developing during a period of right hemisphere growth could be lateralised to the right rather than to the left hemisphere. This lends itself to the possibility that any child developing skills at different times to the normal child could lateralise them to what would be considered to be the abnormal side of the brain. This could apply to a lot of handicapped children. Basser(1962) concluded from a study of hemiplegics that speech was developed and maintained in the intact hemisphere and that in fact the two were equipotential.

Both Mountcastle and Edelman (1978) agree that there is gross localisation of function in the brain but that it exists as part of a precisely connected distributed system and is everywhere functionally more uniform than at first thought. The cortex is organised in columns and each column subserves a particular function in combination with similarly segregated sets of neurons in other cortical regions and in the sub-cortical nuclei. Each of the larger neocortical areas possesses a unique set of thalamic, cortico-cortical, interhemispheric and long descending connections (Mountcastle 1978). The fact that the brain shows ability to adapt after injury is used as evidence that a distributed system exists. One area of the cortex about which he writes in detail is the parietal lobe where he says that all the columnar sets seem to have one particular characteristic in common. That is that their cells are active in relation to actions upon and within the immediately surrounding environment, and also to the spatial relations between the body and its parts, the gravitational field and that environment. This fits in well with the views already quoted about the parietal lobes. Mountcastle stresses the interconnectedness of parts of the brain and comments that although recent research has provided a lot of information it is still impossible to plot a flow diagram to show the structural linkages between the input and the output of the cortex.

Pribram(1971) does not lateralise function at all. He considers that various parts of the association cortex are concerned with particular functions. For instance the infero-temporal cortex is concerned with visual discrimination tasks and visual choice procedures, the occipital cortex with visual imagery and the frontal cortex with short term memory, damage to this area rendering the person stimulus bound and distractible.

<u>Interconnectedness of areas of the brain: the role of the corpus callosum.</u>

Dimond(1972) suggests that the right hemisphere is involved with visuo-spatial functions. If these functions are to be available for drawing with the right hand responses are instigated not by the dominant hemisphere (left), but by the right establishing influence through the corpus callosum. He thinks that there is less lateralisation than used to be thought and that integration of the two hemispheres via the corpus callosum is essential, particularly for abstract tasks.

Harris (in Elliot and Salkind 1975) agrees with the main functions of the two hemispheres and points out that in tactual tasks requiring spatial discrimination it is the non-dominant hand that is best. He cites as evidence the fact that blind people reading braille tend to use their left index finger as they can feel the configurations better this way, and feel them spatially before converting them to digits. He thinks that the spatial function might depend on the convergence of unlike elements, visual, kinaesthetic and vestibular. These combine to create through experience a single supramodal space. The suggestion is also made that early cognitive development is the development of spatial knowledge, a knowledge of the layout of the world, and this will be considered later in the section on cognitive and perceptual-motor development.

Sperry (1969) found that the corpus callosum was essential for the two hemispheres to work together to integrate different parts of the total spatial picture and for unifying the processes of attention and awareness.

According to Gazzaniga (1970), the spatial relationships role of the right hemisphere is integrated with the visual functions of the left hemisphere via the corpus callosum, and there will only be perceptual unity if the corpus callosum and the anterior commissure are intact. Brown (1979) considers that this is necessary for mathematical functioning as well.

In the child below the age of about two the corpus callosum is not fully functional and the child is virtually a split brain organism, with the two hemispheres developing independently. Lesions of the left hemisphere up to this age have little effect on speech. As the child develops, the hemisphere controlling the dominant hand becomes more and more dominant, and as this hand is the one dealing with the environment speech develops in connection with it. Having suggested that the corpus callosum develops with use as does the cortex Gazzaniga even localises parts of the corpus callosum for the transfer of specific perceptual information; with the posterior fifth of it, along with the anterior commissure being responsible for the transfer of visual learning and the middle two thirds of the corpus callosum for visual pattern learning. The anterior part of the corpus callosum is of more importance in integrative and associative perceptual tasks. With Bogen(1965) he suggests that it appears from disconnection studies that the disability of the right hemisphere to respond appropriately to language, is parallelled by a left hemisphere incapacity to respond properly to a visuo-constructive problem. These studies provided evidence of dominance in the minor hemispheres for certain visuo-spatial functions and also illustrated the probable role of the corpus callosum in the simultaneous use of verbal and visuo-spatial thought. In the disconnected patient(Gazzaniga 1966) it was found that activities involving speech and writing were well preserved in so far as they could be governed from the left hemisphere, a fact also found by Milner and Taylor (1978). Visual information did not transfer and the perceptual activities of one hemisphere did not influence the other, because in the intact organism the corpus callosum mediates in those responses in which the sensory input is directed to one hemisphere and the primary motor control lies in the other. It may be the case that the lateralisation and specialisation lies more in the motor executive or expressive sphere than in the sensory perceptual components of the performance. The person may know what the correct response is but be unable to carry it out.

In 1967 Gazzaniga put forward the interesting idea that if a human brain were divided in a very young child, both hemispheres would develop functions of a high order, attained only in the left hemisphere of normal people.

This is only a selection of the main views on the lateralisation of brain function and as they are so varied it is not surprising that no-one is very sure of the specific effects of the brain damage which occurs in Spina Bifida and Hydrocephalus, in terms of intellectual performance.

CHAPTER TWO. NEUROLOGICAL CONSIDERATIONS.

Part 2. Brain damage which may occur in Spina Bifida and Hydrocephalus.

2) Brain Damage which may occur in Spina Bifida and Hydrocephalus.

Books on the neurological aspects of these conditions list a number of parts of the brain which may be damaged or malformed in association with Spina Bifida or Hydrocephalus.The main areas of damage have already been mentioned briefly. One thing which still appears uncertain is the exact connection between Spina Bifida and Hydrocephalus, both of which can occur independently, although in approximately 80% of cases of myelomeningocele(Anderson and Spain 1977) Hydrocephalus is also present, sometimes very evident at birth and at other times becoming obvious later.

Hydrocephalus.

This has already been mentioned to some extent but needs mentioning again in connection with brain damage as its effects are very uncertain. It is reasonable to believe that there must be a critical level at which the damage occasioned by the Hydrocephalus in terms of pressure and ventricular dilatation results in significant forms of brain damage. However many people with some degree of ventricular dilatation have been found to be perfectly normal, or above, intellectually. Recent research by Lorber (1980), in which he has studied Computerised Axial Tomography Scans (C A T scans) of people with Hydrocephalus, in order to find out what effect the Hydrocephalus has on the cerebral cortex produced some interesting results. Lorber suggested that even with a cortex of only 1 millimetre it was possible for an individual to be highly intelligent and quotes a young man with an IQ on the WISC of 126 and a first class honours degree in mathematics who has such a cortex. This man had untreated Hydrocephalus which had obviously spontaneously arrested.

He explains his findings in the following way. The human body is overendowed with organs and the brain is much larger than it needs to be so it is possible that parts of it not normally associated with thinking activities could take over those functions in the absence of significant cortex. He does emphasise that there is no value in comparing people born like this with people who suffer injury as adults as the brains of the young have a lot more plasticity, which can be brought into use when required, thus rendering rigid ideas on lateralisation valueless. The title of Lorber's article and a radio programme he made on the same subject, "Is your brain really necessary", certainly provides food for thought. (The word brain as it is used here means the cerebral cortex.)

However not all Hydrocephalics turn out to be like those mentioned by Lorber so it is useful to look at the damage which may be caused by Hydrocephalus. In this condition the dilatation of the lateral and third ventricles outwards causes pressure, which results in the stretching and thinning of the cerebral cortex particularly at the occipital and frontal lobes. It also results in the stretching and thinning of the corpus callosum which is the main commissure joining the two cerebral hemispheres together. Stretching of the components of the limbic lobe and the long nerve fibres connecting one part of the cortex to another also occurs. McNab (1965) suggests that the nerve cells themselves are not damaged.

It must be remembered that in treated Hydrocephalus, although valves are inserted to control the pressure that is often not the end of the matter. They may block and cause a recurrence of the Hydrocephalus by so doing and this is likely to result in further surgery to replace the valve and to redrain the excess fluid from the brain to reduce the pressure.

The cerebral cortex is the most advanced part of the brain, which is responsible for the higher functions of which humans are capable, such as logical thought. If the cortex is stretched it could be surmised that certain overall brain functions will be affected. Even Lorber(1980) mentions the fact that although some of the individuals with little cortex whom he has studied appear to be functioning normally, this is with present day research methods. He cites the fact that at one time it was thought that patients with a severed corpus callosum could act normally until more refined tests proved that this was not the case. He suggests that at the present time we know about as much about the brain as we knew of bacteria a century ago.

Brocklehurst(1976) suggested that the pressure atrophy of various unspecified structures could be responsible for the particular personality characteristics of these children, which appear to be sociability, combined with a lack of initiative and motivation and general apathy. Price(1979, personal communication), a consultant neurosurgeon, thinks that it is the overall tension and stretching of the cortex which causes the learning problems in these children.

Zeiner and Prigatano(1982) state that previous research has shown that children with Hydrocephalus have substantial cognitive, perceptual and motor deficits which can not be readily explained on the basis of damage caused to the cerebral white matter by the enlarged ventricles. Some Hydrocephalics had been found to have large ventricles and a thin cortex but normal IQs and above average academic performance. However they point out that a normal range of IQ does not necessarily mean that the brain is functioning normally. Specific information processing deficits may be related to the more subtle neuropathological changes which occur in Hydrocephalus and about which little is known at present. They quote Rakic(1979) as having observed that embryologically the relative position of precursor cells lining the cerebral ventricles determines the time and rate of the migration of these cells in the primate neocortex. They suggest that Hydrocephalus may disturb the relative placement of these cells during intra-uterine development. Even though most children with Hydrocephalus are shunted immediately after diagnosis and frequently within five days of birth, intra-hemispheric deficits may already be present as a result of the intra-uterine development of Hydrocephalus.

Tromp(1984) states that;-

> It is to be expected that retention of information will not take place optimally in a brain that is diffusely damaged as in Hydrocephalus.

He mentions speed and accuracy of information processing and memory as being two of the most integrative functions of the brain which are likely to be disturbed.

The Corpus Callosum.

The corpus callosum is the part of the brain that joins the two cerebral hemispheres together and enables integration to take place. In the young child brain damage can often result in the function of a particular area such as speech, being taken over by the other hemisphere. It is possible that children with Spina Bifida have problems of integration of the two sides of the brain due to the stretching of the corpus callosum by Hydrocephalus. The damage possible at this stage should not be very severe as the corpus callosum is not very well developed at birth(Gazzaniga 1970).He also suggests that it will develop through usage in early childhood. This may be where many children with Spina Bifida lose out as they suffer long periods of hospitalisation and immobility during these vital early years. If the child does not engage in activities which demand the integration of the two sides of the brain then there is no activity to encourage these connections to develop. It seems likely that movement and interaction in the early years, must be considered as well as possible brain damage when it comes to discussing educational problems. However before one can form such an opinion it is necessary to consider all the different aspects of the situation.

Gadsdon et al.(1978) produced evidence that the myelination of the corpus callosum is directly affected by the Hydrocephalus. They carried out a quantitative morphological study of the process of myelination of the corpus callosum of 48 children presenting with Hydrocephalus. They found that 77% of these brains showed the presence of the lesion "fatty change"(i.e. glial fatty metamorphosis associated with interference with myelination), and these cases showed the greatest evidence of reduced myelination. Most of the cases of Hydrocephalus showed evidence of delayed or altered myelin formation in the corpus callosum in terms of its thickness, cell concentration, vascularity and myelin.

Further analysis showed that rate of head expansion was related to the level of myelination. From these findings they concluded that Hydrocephalus is associated with a delay in myelination of the corpus callosum either as a direct interference with myelogenesis or as a destructive agency after myelination has commenced. They quote Friede (1963) who found that in 22 hydrocephalic brains which he studied there was no alteration in the myelination of the parietal lobes. They suggest that this area is not as sensitive as the corpus callosum to the stretching and other potentially destructive forces of Hydrocephalus.
In 1979 Gadsdon et al. produced further evidence which supported the view that once Hydrocephalus is controlled the myelination can proceed normally. They studied the brains of 32 children with Hydrocephalus that had been controlled by shunting, finding that the cell and myelination activity of the corpus callosum in these children was within the normal range for children of that age. This contrasted markedly with the findings on children where the Hydrocephalus was in a progressive state.
In some cases it has been found that there is a congenital absence of the corpus callosum in association with Hydrocephalus, which results in an asymmetric growth of intellectual capacities, where either a linguistic or a spatial capacity is developed (Dennis in Blaw 1977). They make no attempt to explain why this should be so.

<u>Other Brain Deformities</u>.

The Arnold Chiari malformation of the hindbrain and cerebellum has already been discussed in detail in the first chapter. Lesions can also occur in other parts of the brain.

<u>Midbrain lesions</u>(Brocklehurst 1976).

Lesions also occur in the midbrain, notably deformities of the Aqueduct of Sylvius through which cerebro-spinal fluid passes. This is another factor which could lead to Hydrocephalus. Deformities of the inferior and superior colliculi also occur. The superior colliculi are involved in visual reflexes, particularly reflex movements of the head and eyes which occur in response to visual stimuli. This includes eye fixation which keeps the gaze on objects of interest. However to take in the whole configuration the visual cortex is involved. Lower animals can distinguish shapes via the colliculi, which also help to judge motion and balance and act as an important way station in the visual system. The inferior colliculi are centres for auditory and some vestibular reflexes.

Forebrain damage. (Brocklehurst 1976)

In the forebrain there is dilatation of the lateral and third ventricles caused by the Hydrocephalus and there are also clusters of cells in the cerebral cortex in abnormal positions. The course of cranial nerves VII-XII is prolonged to reach their foramina in the skull.

Developmental brain damage.

There is one other important side to brain damage that must be considered and that is the effect of the disability of the child on the early development of the brain, where damage can still occur or deficiencies be compounded, as opposed to inherent damage. The environment plays an important part at this stage.

Brierley(1976) suggests that the first two or three years of life may be a period when the brain has a once only opportunity to grow properly. At this time the normal child is exploring the environment with many senses and this activity combined with proper feeding and a good language environment is likely to be influencing nerve growth. As mentioned in the fourth chapter, Epstein(1981) claims that his experimental data show definate growth stages and plateaux in brain development. The main period which concerns us here in addition to the first two years is that from two to four. At this stage he states that the brain is being programmed for binocular vision, hearing, language and speech at this time. Workers trying to help very young children to overcome physical handicaps should be aware of the much better prognosis if their efforts are concentrated during this spurt period. This seems to be an idea which has been generally accepted for some time in this country as nursery education has been encouraged for such children. All the children considered in detail in the case studies to follow had the benefit of nursery education. It may be possible to utilise later spurt periods to catch up but for some functions this early stage appears to be critical. One such function is the development of binocular vision. Brierley (1976) states that the brain is vulnerable to the effects of abnormal vision before the age of three and that squints can have a profound effect even if corrected. The visual centres of the brain depend for normal development on normal input from the eyes and that is particularly crucial for the development of binocular vision, which depends on close matching of inputs to either eye. Some neurobiologists think that the matching input guides the development of nerve cell connections linking brain cells fed by one eye with those fed by the other. It is on such connections that binocular vision and thus the ability to see in depth depends. Childhood squints left uncorrected for too long commonly result in the loss of binocular depth perception and even in partial loss of vision in the deviant eye. It seems that this is because the binocular connections fail to develop and the normal eye captures the brain cells for its exclusive use. This is the view of Blakemore and Cooper(1970) who experimented with cats in different visual environments and found that early visual experiences modified their brains and caused profound perceptual consequences. It could be that the nervous system adapts to match the probability of occurrence of features in its visual input. Although these writers are not talking about children with Spina Bifida their findings are nevertheless relevant. Many children with Spina Bifida have squints and due to the necessity for a lot more serious operations in early life it is often many years before they are treated. Some of the squints are not in fact treatable other than cosmetically. It is possible that the sort of permanent damage described here has occurred in these children, and that this combined with an unstimulating early environment due to immobility, could contribute to the existence of perceptual problems.

Alberman et al.(1971) found that in a national sample of British children 3.5% had squints at the age of 7 years and in 43% of them the vision in the better eye was less than perfect. They found that the prevalence of cerebral palsy, mental subnormality or clumsiness in these children was twice that of a control group and the proportion of those with poor speech, left or mixed handedness, or signs of maladjustment was significantly raised. Having excluded children with obvious signs of brain damage they found that the children with squints tended to show other signs of neurological dysfunction and suggested that many squints may be due to central rather than opthalmological causes. They make the suggestion that children with squints are a handicapped group.

Tew and Laurence(1978) mention this work and also that of Clement and Kaushal (1970) who found that 51% of a group of children with myelomeningocele suffered from a squint compared with a group of Spina Bifida children all with shunt treated Hydrocephalus where the incidence was 81%.

Tew and Laurence (1978) examined 55 South Wales children with Spina Bifida close to their 10th birthday, along with 55 normal controls, one of which had a squint, The WISC, Neale analysis of reading and items from the Stott test of motor impairment were used. Of the children with Spina Bifida 40% were judged to have an ocular defect other than merely refractory errors. This was found to be significantly related to shunt treated Hydrocephalus and also to the more severe physical handicaps. These children showed a significant verbal-performance discrepancy on the WISC. They found that the children with ocular defects had serious intellectual impairments with an overall level just above the severely subnormal. Even so their school attainment fell short of what could be expected for their intelligence and they showed great difficulty in hand-eye coordination, taking three times as long as normal children to complete a simple task.

Spain (1974) found that at least 25% of the children with shunts for Hydrocephalus in her study had squints and suggested that most of them would never have achieved binocular vision. She found that many of the children had perceptual problems as well as manipulative ones.

Brierley(1976) also says that any <u>hearing defect</u> not corrected early on is likely to have a permanent effect on language development, again with the years two to four being the most vital. This is less applicable to Spina Bifida children as hearing problems are infrequent and they are often hypersensitive to sound. Anderson(1975) suggests that this is due to some neurological function disturbance caused by the Hydrocephalus.

Although the human brain is more flexible than that of other animals as regards critical learning periods and therefore some catching up can be done in cognitive development, the earlier this can be started the better. It seems likely that the generalised stretching of the cortex and corpus callosum, combined with the myelination defects of the latter, along with visual and coordination problems are all likely to have an effect on intellectual development. In addition the brain must be considered as part of the sensory-motor system as it does not operate independently.
In addition to the neurological factors there will also be environmental factors influencing development, with interaction with the environment and movement in early childhood being of great importance. Taking all these factors into consideration, one would expect these children to have learning problems, particularly in certain areas. However if equipotentiality of the hemispheres and the fact that early development of the brain can be influenced are considered, then there would appear to be possibilities of improving the situation.

CHAPTER TWO. NEUROLOGICAL CONSIDERATIONS.

Part 3. Defects in the sensory-motor system.

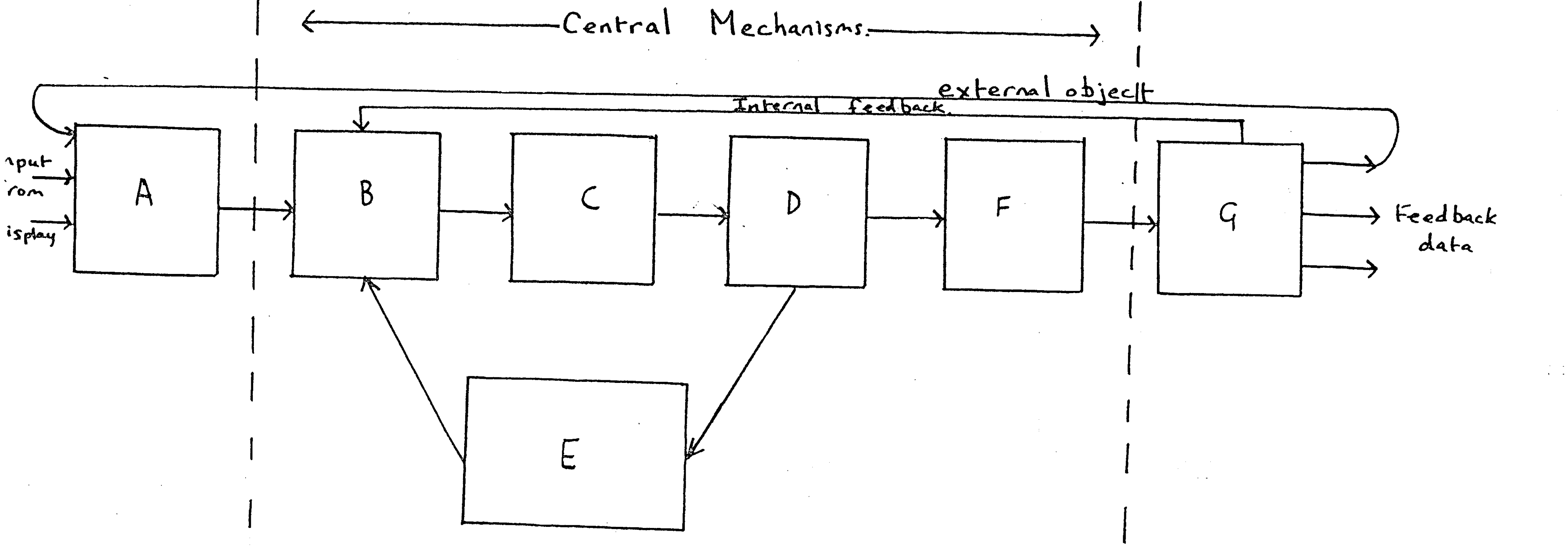
3) Defects in the sensory-motor system.

The brain does not operate independently. It is part of the system along with the sense organs and effector organs and a defect in any part of the system can have a far reaching effect. The senses need to be considered as active perceptual systems, that is an active eye(or ear) in an active head on an active body. It is possible to have defects in the sense organs or the brain which will cause problems, but even if everything goes well to this stage the passage to the effector organs and the organs themselves must be fully functional for success. Figure 13 shows a model of the human sensory-motor system which shows where things can go wrong and it is useful to briefly consider all these possibilities and how they might relate to the problems shown by children with Spina Bifida and Hydrocephalus.

Stimuli can attract the attention of the subject or the subject can be actively attending to a particular stimulus. An active subject will orient his sense organs towards the stimulus. Solley and Murphy(1960) call this scanning and consider it to be essential for all perception. In order for this orientation to take place the subject must be aroused and attending. There is an optimal level for arousal, if the level is insufficient then nothing will be taken in, but if it is too great then the subject's perceptions will be confused as there will be too much cortical activity going on and the 'noise' will drown out the important signals. Arousal seems to be caused either by impulses from the brain stem reticular formation or the thalamic reticular formation activating the cortex, or from hormonal influences.

As already mentioned attention to stimuli can be voluntary or involuntary and people biased towards involuntary attention are distractible and cannot concentrate. This is a characteristic of many brain damaged children including many of the children with Spina Bifida and Hydrocephalus. Human beings cannot process a lot of different pieces of information at once so if they try to attend to a lot of stimuli learning is unlikely to take place. Attention has to be selective and this will be influenced by extraneous factors such as memory and mood. Attention is very much a

Model of the human sensory motor system, showing some of the possible feedback loops.
(From Welford 1968, Whiting 1975)



A Sense organs.
B Perceptual mechanisms.
C Short term memory.
D Translation from perception to action.
E. Long term store.
F. Control of response,
G. Muscular system, effectors.

Figure 13.

skill in its own right and should therefore be trainable to some extent. Active perception entails stimulation from the environment via the senses as well as stimulation from the actions and reactions of the subject. This action produced stimulation is called reafference, which is a particular form of feedback and will be considered later. Sense organs on their own do not perceive. It is possible in fact for the eyes to see, but because of damage to the visual cortex not to perceive and not to know that they see. Colin Blakemore in his 1976 Reith lectures described the phenomenon of 'blindsight' where due to damage to the visual cortex the patient did not know that he could see, but when asked to point to where a light had been flashed could do so. This is because the eyes send signals to the more primitive parts of the brain, the superior colliculi, which are the source of sight in lower animals. These provide the information for this task. Blakemore states that the cortex is the home of conscious perception. It will also be the part of the brain which will make the decision as to where the attention will be directed, and will control the response as a result of its perception of the situation. Problems can occur in the sense organs which will obviously affect perception, but as has already been mentioned early visual defects can affect the development of the cortex and therefore affect future perceptions. If the sense organs are not aimed correctly the wrong information will be picked up. Many people with brain damage are found to have defects of central vision which causes difficulty in fixation of the eyes. Once the aiming has taken place the relevant information must be selected, which is a part of the system where the children under consideration have problems, often responding to irrelevant stimuli. Wedell(1973) suggests that disturbances of input functioning are more handicapping than those of output since the former are liable to distort the information on which the child builds up his concepts of the world around him. Assuming that the correct information is picked up then the correct response has to be initiated and feedback from the initial response can modify further responses. If there are problems in the effector organs or in the feedback mechanisms the whole system will be affected.

Reitan(1970) found in two groups of minimally brain damaged children that those with impaired cross sensory functioning(sensory-motor) did more poorly on intelligence tests. He used the findings to support the idea that there is a relationship between sensory-motor impairment and higher level cognitive functions. Many children with Spina Bifida have coordination problems in their upper limbs and paralysis in their lower limbs. Thus in these children it is possible for defects to occur at any or all stages of the system, which adds to the complications of considering the causes of their learning problems, both general and specific.

Chapter 2.- Summary.

In order to understand fully the problems of children who have suffered damage to their central nervous system, such as those with Spina Bifida and Hydrocephalus, it is necessary to have some understanding of the neurological aspects, but these need to be related to other factors as well. Neurological aspects are considered in this chapter and other factors such as environment later.

The point is made that mental activity is a very complex functional system which may involve widely different parts of the brain. Thus care should be taken not to ascribe a simple cause-effect relationship between damage to the brain and performance (Luria 1973).

Some of the main views on lateralisation of brain function are considered and generally agree that there are dominant and minor hemispheres with different functions.

Some of Luria's (1973) ideas are given and would suggest that the problems shown by children with Spina Bifida and Hydrocephalus are indicative of general damage affecting several lobes rather than damage to a specific area. This would seem a reasonable idea as there is generalised stretching of both the cortex and the corpus callosum as a result of the Hydrocephalus. The fact that Hydrocephalus affects the myelination of the corpus callosum is also mentioned (Gadsdon et al. 1978).

The role of the corpus callosum in integrating the two hemispheres is stressed and the fact that it is thinner than normal or in some cases is missing altogether is mentioned as a possible factor in some types of learning problems. Mention is also made of other brain defects associated with Spina Bifida and Hydrocephalus, which may also have some effect on learning.

Views on equipotentiality of the hemispheres (Corballis and Beale 1976) and plasticity of the brain due to a massive overprovision of brain cells (Lorber 1980) are also considered along with Lorber's suggestion that the present level of knowledge on the brain is about the same as that on bacteria a century ago.

The effect of squints on the development of binocular vision are discussed, with Brierley(1976) stating that they must be corrected by the age of three years if the effects are not to be permanent. The point is made that this fits in well with Epstein's view that the brain growth spurt between 2 and 4 years is crucial for the development of binocular vision, hearing, language and speech. It is also suggested that the correction of squints may take place too late in the children under consideration due to the urgency of life-saving operations early in life.

Consideration is also given to the many places in the sensory motor system where problems can occur in these children with attentional deficits being singled out as one of the main problem areas.

It is obvious that views on the effects of the brain damage in these children are very varied and thus no definite statements can be made. At an educational level it is sufficient to realise that there are problems which are not easily explained or solved as the situation is far more complex than it may at first appear.

CHAPTER THREE.

PREVIOUS RESEARCH ON THE INTELLECTUAL ABILITY OF CHILDREN WITH SPINA BIFIDA AND HYDROCEPHALUS, WITH PARTICULAR REFERENCE TO MATHEMATICAL ABILITY.

Part 1. Intellectual development.

Previous Research on the Intellectual Ability of Children with Spina Bifida and Hydrocephalus, with Particular Reference to Mathematics.

Much of the research into the intellectual ability of these children has been carried out on small samples but there have been two large scale longitudinal studies in this country. These are the GLC studies of Spain, Carr, Pearson and Halliwell(1967-84) and the work of Tew and Laurence in South Wales since 1966. Lonton has assembled data on over a thousand children at Sheffield Children's Hospital and has reported many of his findings since the early 1970s. There have been some contradictory findings in these three major studies which will be discussed later.

It is necessary to look at reports of research carefully in order to ascertain whether the author is describing a conservatively treated sample(born prior to 1961/2 in most areas of the UK, 1959 in Sheffield) such as Badell-Ribera et al.(1966) and Tew and Laurence (1972), or an aggressively treated sample(born 1961-1972 approximately) such as Lorber (1971) and Tew and Laurence(1975). After 1972 selective non-treatment began in major centres such as Sheffield so three different regimes are represented , often in the same research report, for instance, Lonton(1982). In the conservatively treated groups the more severe cases are likely to have died leaving a sample with a milder condition. In the aggressively treated group a very wide range of children is involved including some who are grossly handicapped both physically and mentally. In the selected group again the condition tends to be milder. However as the criteria for selection are not foolproof some severely handicapped children may be contained in this group, as in the early untreated groups where some of them survived despite lack of treatment. The selected group is likely to be drawn from a smaller total population of Spina Bifida births due to the effects of screening for neural tube defects. Sklayne (1981) found the selected groups to be better intellectually than previous groups.

Although most teachers of these children will point to number work as being a major problem area, very little research has been done on this subject.

Parfitt(1979) and Gibson(1981) have reported research specifically in this area. Gubbay(1975), when writing about clumsy children, suggested that the lack of information on children with impaired mathematical ability was due to the fact that it was a more socially acceptable problem than illiteracy, and therefore attracted less attention.
Tew(1983) concludes that his study confirms that Spina Bifida is a complicated condition in which many variables interact to affect psychological performance.

Intellectual Development.

Anderson and Spain(1977) make a very important point about the assessment of young Spina Bifida children. That is that because many of them are very fluent verbally they give an initial impression of being intelligent and some of those dealing with them wonder why learning problems occur later. This fact is supported by reading the early records of the children considered in this study, particularly those written by medical practitioners. Swisher and Pinsker(1971) carried out a small scale study of eleven shunted children with Spina Bifida and Hydrocephalus, who were rated as hyperverbal, and compared their performance with a control group. They stated that the clinician could overestimate the intellectual potential of these children if he relied purely on verbal output. Menelaus(1980) also had cause to comment upon the tendency to overestimate the intellectual abilities of Spina Bifida children in this way.
Five major points are made by Anderson and Spain(1977) about the general intellectual development of these children, all of which are considered in a number of pieces of research.

(i) The intelligence of most children tends to be below average.

(ii) There are generally marked differences between the intelligence levels of children with and without Hydrocephalus, which are related to its severity.

(iii) Intelligence does not necessarily vary with the severity of the physical handicap unless there is also Hydrocephalus.

(iv) To some degree there are differences related to the nature of the lesion.

(v) Not all intellectual functions are affected equally, with verbal skills tending to be less impaired than performance skills.

In the years since 1977 these points have all been raised in research which has shown that they are generally correct but require refinement.

The most common measure of intelligence used in educational research is the Weschler Intelligence Scale for Children (WISC) or the equivalent for young children (WPPSI) both of which have verbal and performance scales, each consisting of five or six sub-tests which are scored to produce Verbal, Performance and Full-scale Intelligence Quotients. Arguments can be made for and against the use of standardised tests but at least they provide some common ground for the comparison of groups of children.

The Distribution of Intelligence.

Laurence and Tew(1971) studied the survivors of a series of 425 cases of Spina Bifida born in South Wales between 1956-62. Most of this group of 63 children had not been surgically treated. The authors point out that this series represented the natural history of the untreated Spina Bifida child and could therefore be used as a baseline against which to evaluate modern treatment.

The group contained a large proportion of milder cases of Myelomeningocele who had avoided severe paralysis and incontinence. Laurence and Tew suggest that a surgically treated series should perform better intellectually as the Hydrocephalus would be checked. This could also work in reverse as some of the more severe cases who would previously have died would be kept alive. This view is in fact supported by a comparison of the figures produced by Laurence and Tew(1971) and Tew(1983) for the myelomeningoceles, as follows:-

1971 - 18 conservatively treated - mean IQ 89.89(SD 21.55).

1983 - 44 aggressively treated - mean IQ 77.5(SD 24).

Thus it would appear that due to medical treatment a much larger number of myelomeningoceles had survived but were intellectually inferior to the early survivors. Tew(1983) suggests that the meningoceles should be considered to be an atypical Spina Bifida population. Laurence and Tew(1971) found a mean IQ of 94(SD 17.48) for 37 conservatively treated children with meningocele and Tew(1983) found a mean of 101.7(SD 11.5) for 9 such children.

Lorber(1971) and Hunt and Holmes(1975) in their research show that even with aggressive treatment the IQ scores are skewed towards the lower end of the scale with the peak falling between 70 and 90.This does not mean that there are no children of high intelligence but they are not very common. Scores on a test such as the WISC show great variability and Tew (1983) demonstrated this by reporting a Standard Deviation of 24 for the myelomeningocele group, which was twice that of both the controls and the meningoceles.

Research on the distribution of intelligence shows a great deal of agreement in several centres around the world. Lorber(1971) found in Sheffield that approximately 33% of patients with myelomeningocele, treated from birth, had an IQ of below 80 on the WISC.

Halliwell et al.(1980), in London, found that more than 50% of such children had an IQ of below 85 on the WISC.

Menelaus(1980), in Australia, states that between one third and two thirds of the children have an IQ of above 85 which fits in well with the above findings.

In Sweden Liedholm et al.(1974) in assessing children of pre-school age on the Griffiths Developmental Scale found that one third of the children were below average mentally and one half at an average level.However it must be remembered that although a developmental scale such as Griffiths can give a guide as to future intellectual potential it is not directly comparable to an IQ score. Even so their figures are very similar to those of other researchers who used the WISC . In the light of Tew's findings(1983) that IQ scores vary little from the age of

five in cases where there is no further cerebral insult, it would seem important that the child is given the opportunity to develop in as near normal a way as possible.
Tew(1973) found that detailed psychological testing over a period of six years gave test scores which varied by less than five points for the group as a whole, although there were some large losses. He comments that although it is generally accepted that IQ scores are good predictors of school progress his findings indicate that this assumption must be viewed with caution as the attainment results tended to be poorer than expected. He also states that the South Wales study showed a significant difference in IQs between males and females with full scale scores on the WISC of 83 and 74 respectively, compared to 108 and 103 for the controls. This he suggests reflects the fact that the more severely affected males die early whilst the girls survive but with seriously damaged intellect.
Tew and Laurence(1972) had commented on the languid, apathetic attitude of the children during testing which they felt may reflect a general lack of motivation which could be connected to the effects of Hydrocephalus. This sort of attitude may in itself affect test results.
How retarded a child is can be looked at in relation to how intelligent he would have been expected to be had he not been handicapped. This of course is a hypothetical question, but as the scores of Spina Bifida children do not follow the normal curve of distribution something other than the normal factors which affect intelligence in the population is at work.
Tew and Laurence(1973) produced some interesting findings when they studied the intelligence of families which contained Spina Bifida children. They studied 59 Spina Bifida children and their 44 siblings and 59 matched controls and their 63 siblings. The Stanford-Binet Intelligence Test was used for the two to seven year old siblings and the WISC for those from eight to fifteen. The Spina Bifida children who were five and a half years old were given the WPPSI, apart from two who were so mentally retarded that the Griffiths developmental scale was used. The difference in scores between the Spina Bifida children and their siblings

was highly significant and did not reflect social class membership. They therefore ascribed them to maldevelopment of, or damage to, the central nervous system. They found that those with myelomeningocele had significantly lower scores than those with meningocele and their siblings.
The interpretation of intelligence test results is given a different slant when examples are considered, such as a girl with a high lumbar lesion and moderate hydrocephalus who had an IQ score of 106 on the WPPSI. This is within the normal range and it would be tempting to conclude that her intelligence was unimpaired. However, when the information is presented that the IQs of her siblings were 141, 142 and 146 it would appear that her intelligence has been markedly depressed. In the case of a family with an average IQ of 100 a similar drop would place the child in the educationally subnormal range.
Lonton(1980) found Spina Bifida to be slightly but significantly more common in the lower social groups. In addition to the social and economic disadvantages of being born into Class Three(manual) and below, these children were also found to have lower intellectual skills, particularly on verbal tests, lower attainment in reading and a lower chance of attending normal school.
Carter(1969) states that there is a ratio of 1.3 girls to 1.0 boys with Spina Bifida and that among the survivors the girls tend to be more physically handicapped with a higher proportion requiring shunts. Spain(1970) found that 70% of the girls were shunted compared to 50% of the boys. Such reasons help to explain why there are more girls at the lower end of the IQ range.

Effects of Selection.

Sklayne(1981/1982) studied 99 children with Spina Bifida who attended special schools in Manchester. Of this group 57 had been treated prior to selection and 42 afterwards and she found that the two groups appeared to be entirely different populations. The former group had been treated regardless of their degree of handicap. The pre-selection group had a mean IQ of 84.7(SD 16.5)(Verbal 91.1-SD 16.9, Performance 80.3-SD 15.3)and the post-selection group 101.7(SD 15.4) (Verbal 106.1-SD 13.9,Performance 98.1-SD 16.1), with the difference being significant at the 0.0005 level. The

difference in Reading Quotients was significant at the same level with means of 79.7 (SD 22.9) and 102.5 (SD 23.5) respectively. In terms of mobility the post-selection group was far less handicapped with only 14.3% in wheelchairs compared to 58.9% in the pre-selection group. 71.4% of the post-selection group walked with aids compared to 30.4%. There was also a slight difference in unaided walking with more children using this mode of locomotion after selection being 14.3%, compared to 10.7% before the introduction of selective surgery.
It is possible that the younger children in the post-selection group had not reached the stage where many children give up using calipers and use wheelchairs full time. However the difference is so great that a more likely explanation is the milder degree of physical handicap in the post-selection group.
Sklayne (1981/2) found a lower incidence of perceptual difficulties in the post-selection group but still found slow hand speed. She also compared the performances on the WISC and in reading of the Spina Bifida children in special schools and those in normal schools. For the post-selection children the only significant difference was on the WISC arithmetic sub-test(P= 0.017) with those in special school performing at a lower level.

Verbal and Performance Aspects of Intelligence.

As has already been mentioned the main test used in research is the WISC which is divided into Verbal and Performance sections. Many people(Badell-Ribera et al. 1966, Anderson and Spain 1977, Lonton 1979) writing about children with Spina Bifida state that Performance IQ tends to be poorer than verbal IQ and that poor visuo-perceptual functioning links up with the poor performance IQ(Miller and Sethi 1971). Tew and Laurence(1972) disagreed with Badell-Ribera et al. and suggested that poor visual perception is strongly associated with low intelligence generally, and stated that they had not found the same differences between the verbal and performance scores on the WISC, as had the other researchers. Their results were as follows:-

	N	VIQ (SD)	PIQ (SD)
Meningocele	17 children	95(15.8)	93(12.5)
Encephalocele	9 children	61(20.9)	52(22.3)
Myelomeningocele	32 children	94(20.4)	85(19)

The highest discrepancy shown is nine points in the myelomeningoceles and the encephaloceles which are the two groups with the most disability. However as this is a conservatively treated group there is less chance of it containing severely disabled children. In 1975 they reiterated these points about the connection between poor visual perception and low intelligence.

Halliwell et al.(1980) found in a group of eleven year olds with Spina Bifida in Greater London that there was only a small difference between verbal and performance scores even for those with shunts in whom scores were generally depressed.

	N	Verbal IQ.	Performance IQ.
All children	103	89.5	84.0
With shunts	67	84.3	77.4
No shunts	36	99.8	100.4

Andrews and Elkins(1981) also found only small differences although there was a greater discrepancy in the shunted children.

	N	Verbal IQ.	Performance IQ.
With shunts	42	82.5	75.5
No shunts	29	85.1	86.1

Tew(1973) comments that verbal/performance differences are likely to be greater in children of average intelligence and above, due to the greater variability of scores in this range. As children with Spina Bifida and Hydrocephalus tend to have below average intelligence he would not expect such differences to occur.

This is in direct contrast to Anderson and Spain (1977) who suggest that the verbal/performance discrepancy is the greatest in the children with an overall IQ of less than 80.

Lonton(1979) found in a group of 302 children that the mean verbal IQ was 101 and the mean performance IQ 85. This shows a 16 point discrepancy which might suggest real problems in the performance area. When he broke the differences down according to degree of Hydrocephalus the greatest differences occurred in the two groups with the largest ventricles. There were six groups in total and the two with large ventricles had discrepancies of 19 and 20 points.

However Field(1960) produced tables showing the percentage of the normal population who could be expected to obtain certain discrepancies between the two scales on the WISC. For instance 10% of the population would be expected to have a discrepancy of 22 points at the age of seven and a half and 19.7 points discrepancy at the age of ten and a half. If this percentage of the general population can be expected to show such a discrepancy then it is not safe to assume that it is an abnormality of Spina Bifida children unless a greater percentage show this trend.

Dennis et al.(1981) commented that as overall IQ scores increase, the proportion of normal individuals with higher verbal than performance scores increases. As a property of the test rather than of any abnormality the relationship between the two scales changes with the two being most similar at the average level. This is in general agreement with Tew(1973). She produced a formula for working out a verbal/performance discrepancy score in order to compare the IQ patterns of children from different parts of the intelligence spectrum. This compares relative rather than absolute differences.

Tew(1983) comments on the fact that in his South Wales study and in the GLC study the differences between verbal and performance IQ were not significant whereas Lonton(1979) had found significant differences in his Sheffield study. He puts forward two possible reasons for this state of affairs which are:-

(i) Isosorbide was used in some of the Sheffield cases which may have delayed or avoided surgery. This possibly diminishes ventricular expansion whereas surgery gives rapid relief and restores the cerebral mantle, perhaps resulting in higher performance scores and overall intelligence. Soare and Raimondi(1977) in commenting on their findings that intelligence in their sample was higher than normally quoted suggested that shunting all children with Hydrocephalus early may be the reason. They found a mean IQ of 87.7 for 132 myelomeningoceles and 102.3 for 40 meningoceles. None of the latter group had Hydrocephalus. They insisted on neuroradiological evidence of ventricular enlargement and raised intraventricular pressure before the diagnosis of Hydrocephalus was made, but once diagnosed

it was treated.
However Tromp(1984) found that the timing of surgery had no bearing upon IQ and suggests that it is a rather ambiguous variable. A decision to operate without delay may mean that the patient is deemed to have a very good prognosis or it may mean that the patient would have a bad prognosis if treatment was delayed.
The group from the Sheffield study who were treated with isosorbide will be looked at in more detail in the research in this study to see if Tew's premise is supported.
(ii) The second reason suggested is sample selection. The South Wales and GLC studies were both community based whereas Sheffield was hospital based. This possibly meant that the milder cases were not included in the latter as they were less likely to need to return to the hospital for follow up.

Verbal Skills.

Because they tend to be hyperverbal it is often thought that these children have good verbal skills but this is not necessarily so.
Spain(1972) found that 40% of the children she studied who had shunt treated Hydrocephalus and severe physical handicap were hyperverbal, but did poorly on intelligence tests. They had good syntax and vocabulary but a poor ability to use language expressively. In 1974 she reported that the majority of Spina Bifida children without shunts had normal vocabulary skills at three years of age whilst only about one third of the shunt treated group fell into the normal range on the Reynell test.
Anderson(1975) found that 75% of the Spina Bifida children she studied fell into the normal range on the English Picture Vocabulary Test.
Spain(1974) found that even among children with shunts and low performance IQs the syntax used was appropriate for their age. At six years of age in some cases more complex syntax was used than by normal children but it was not always used appropriately. It is the appropriateness of speech which seems to be a weak area in these children. On the Renfrew bus story test where the children are asked to repeat a story after it has been told to them by the examiner the Spina Bifida group used as many words and clauses and only

slightly shorter sentences than normal children despite the higher proportion of children with low ability. However the information scores, particularly those of the shunt treated children, were poorer than the controls. Many of the low scorers were rated as hyperverbal; that is they had fluent speech coupled with poor understanding. Tew and Laurence(1972) found that 28% of their sample showed this behaviour and they were all of below average or subnormal intelligence. Of the 40% found by Spain(1974) to be hyper-verbal only 20% were assessed by her to be severe cases. Typically such children were female, had shunts and were of low intelligence with a considerable verbal/performance discrepancy on the WISC. They also tended to be more physically handicapped and were rated by their teachers as restless,fidgety and inattentive. She concluded that they exhibit a basic failure to inhibit irrelevant responses. Ingram and Naughton(1962) examined children who had cerebral palsy and found a number who had Hydrocephalus. They were found to have a higher verbal than performance IQ and were sociable and appeared bright but had no depth to their knowledge.These were similar findings to those of the people who studied children with Spina Bifida.

The 'cocktail party syndrome' is a term frequently used in talking about the verbal ability of children with Spina Bifida and Hydrocephalus. Tew and Laurence(1979) established criteria for assessing whether or not children fell into this category. These were:-

Fluent and well articulated speech.
Verbal perseveration.
Excessive use of social phrases.
Irrelevant verbosity.
Over familiarity of manner.

The children who showed three or more of these character-istics were said to show evidence of the cocktail party syndrome. They identified 40% of a group of 59 children as showing this syndrome at the age of five. In comparison with the other 60% of the group who showed meaningful speech these children tended to have more severe physical handicaps and to be of significantly lower intelligence. At the age of seven there were significant differences between the two groups in school performance. Reassessment at the age of ten showed that almost half of the children no longer showed this syndrome but that those who did were grossly retarded.

Fleming(1968) studied the verbal ability of children with Hydrocephalus and she also found that as a group they produced more irrelevant verbal responses than their matched controls.This was despite the fact that she had a carefully selected sample of eleven children of normal or near normal intelligence who had no serious physical handicaps.

Parsons(1968) also investigated the verbal ability of Hydrocephalic children because test results seemed to suggest that they had better verbal than performance skills. One of his main testing instruments was the Mill Hill Vocabulary Scale and he found that the Hydrocephalics did not show up as particularly good verbally compared to normal children. In 1969 he investigated short term verbal memory in the same type of children and found that they did not differ from matched controls. He concluded that their verbal skills only aroused comment because they appeared to be good in relation to other areas. This agrees with the findings of Anderson and Spain(1977) where the verbal skills were superior to the performance skills particularly when both were depressed.

Speech and hearing cause little problem for Spina Bifida children. They tend to be hypersensitive to sound which Anderson and Spain(1977) suggest may be due to some disturbance of neurological functioning. Spain(1974) found that only three out of 145 children had a serious hearing defect and that even at the age of three very few children had articulation defects. Anderson and Spain(1977)suggest that it is possible that auditory perception develops slightly faster than normal in children with Spina Bifida. The acuity of hearing and the rapid development of the ability to distinguish between sounds is beneficial in that it facilitates language acquisition at an early age.

As has already been mentioned (Swisher and Pinsker 1971) it is the early development of language among these children which may give a false impression of their intellectual ability.

Performance Skills.

Miller and Sethi(1971) made the statement that children with Hydrocephalus have lower than average mean IQs when assessed on tests of general intelligence. The question they raise is whether this represents a global deficit in all kinds of intellectual functioning or whether some functions are more affected than others. They cite the fact that in a group of children with Spina Bifida and non-progressive Hydrocephalus Badell-Ribera et al.(1966) found that performance IQ was lower than verbal IQ on the WISC and suggest that this might indicate that perception of visuo-spatial relationships suffers impairment. Miller and Sethi tested a group of Hydrocephalic children on the Frostig Developmental Test of Visual Perception and the Bender Gestalt test and found that on Bender no subject came within eighteen months of their chronological age with the Frostig scores being similarly depressed. They stated that this showed that the children had severe problems in the areas measured by these tests which they described as:-

(i) An inability to perceive a presented shape in its totality and to appreciate its particular spatial configuration or Gestalt.

(ii) Difficulty in figure-ground discrimination or in extracting a given spatial configuration from a conflicting background.

Had this piece of research been left at this,the critisism could have been made that the motor control needed to use a pencil to complete these tests distracted from the task in hand. However they tested this by performing an experiment on matching tachistoscopically to eliminate the motor control factor, and found that the results were very similar. This led them to think that the motor problem was not the predominant one shown up in these tests.

The Frostig Developmental Test of Visual Perception has been used frequently in research and is broken down into five areas. There is some debate among psychologists (Sugden 1984 in Levy and Goldstein) as to whether the test does measure five specific functions rather than just one general visual perceptual factor. Sugden(1984) in his recent review of the test comments that it is useful in giving an overall evaluation of visual perception rather than specific details of visual perception related to learning difficulties.

Tew(1983) in a further study of his 1964-66 cohort of Spina Bifida children stated that when the Frostig test results were compared with attainments measured four and a half years later(at 5½ and 10 years) the intercorrelations were mostly insignificant among the controls but were highly significant in the Spina Bifida sample, suggesting that poor performance on this test at the age of five years was predictive of later educational difficulty in the handicapped group only. His findings for normal children support the view of Sugden(1984) but the difference in the Spina Bifida group is interesting. Tew(1973) reported that he had found five and a half year old Spina Bifida children to have an average lag of 19 months on the age equivalents for the Frostig sub-tests. This ranged from 15 months on Test 5 (spatial relationships) to 23 months on Test 1(eye-motor coordination). The reasons he suggests for these problems include structural damage to the brain and environmental factors such as restricted movement in the early years of life.

Sand et al.(1973) studied 37 Spina Bifida children from a congenital defects clinic 26 of whom had Hydrocephalus. The children were aged four to sixteen and 60% failed to show age appropriate performances on the Frostig sub tests. They did find that lower scores were associated with Hydrocephalus and higher lesions, both of which will be looked at in more detail later. Like Tew(1973) they suggest a combination of brain damage and experiential deprivation as the possible cause of these problems.

Soare and Raimondi(1977) found that in their sample of 173 children with myelomeningocele, perceptual-motor difficulties were more prevalent among those who had spent the most time in hospital before the age of five years. They found that this deficit did not only occur in children of low intelligence, which had been suggested by Tew and Laurence(1972), and suggested that the reasons for it were those already suggested above, being a combination of the brain damage associated with the Arnold Chiari malformation and poor opportunities for exploration during early hospitalisation.

Anderson(1975) used the first three Frostig subtests with Spina Bifida children and compared matched groups of non-handicapped and cerebral palsied six to nine year olds. She found no difference between the groups on the shape constancy subtest but well over half the Spina Bifida children compared to four fifths of the cerebral palsied children and one third of the normal children were below Frostig's criteria for normality on hand-eye coordination. In the figure-ground area two thirds of the Spina Bifida children, four fifths of the cerebral palsied and less than half of the controls had severe problems. The children with cerebral palsy were markedly poorer than even the Spina Bifida children. The finding that figure-ground was the main problem area was very much in agreement with Miller and Sethi(1971).

Spain(1972) found that shunted children at age three tended to have higher verbal than performance scores on the WPPSI. She found that scores on scales requiring spatial skills were low and that the children often forgot what they were asked to do and became confused about sequences of activities needed for success. When asked to copy simple designs with matchsticks which required a minimum of motor control they still had problems. She found that hand-eye coordination was a very weak area. It has been established that many children with Spina Bifida have impairment of manual control and abnormalities in the neurological functioning of the upper limbs(Wallace 1973). This has already been discussed in the first chapter.

The type of problem which shows itself on intelligence tests gives some idea of the factors which may affect future school attainment. Although manual control and visual perception are problem areas other factors can also play a part. The children may have problems in scanning visual stimuli due to neurological impairment, ocular defects or inefficient strategies. Areas such as the latter are open to improvement in order to make the best use of the child's potential, however limited.

Anderson and Spain(1977) advocate intervention in the pre-school years in order to minimise the difficulties caused by neurological abnormalities combined with deprivation of normal experiences.

Intelligence and Hydrocephalus.

The presence or absence of Hydrocephalus has already been mentioned on a number of occasions in the more general considerations of the intellectual abilities of children with Spina Bifida. It is however such an important area that it merits separate consideration.

General statements are often made that it is the presence of Hydrocephalus which is the deciding factor in the intellectual development of these children.It will be seen from the research mentioned that this is an over simplification.

Fulthorpe(1974) estimated the IQs of Spina Bifida children using Raven's Matrices, which on its own is not necessarily the best IQ measure, although it is a very useful measure to use in a school setting. He drew up a summary table to compare his findings with those of other people, and found a fair measure of agreement to support the generalisation about Hydrocephalus given above.

		Hydrocephalus	No Hydrocephalus
Fulthorpe	1973	78	90
Stephen	1963	75	95
Lorber	1971	79	87
Lorber	1972	79	92
Parsons	1967	84	92

Tew and Laurence(1975) found that children with Spina Bifida tended to fall into the below average IQ range which they state as being 70-90, but found that even children without diagnosed Hydrocephalus were affected, although not as badly. This immediately throws up one of the problems which confounds any statistical work on these children. Some children have diagnosed Hydrocephalus which has been treated by a shunt, with variable effects. Others have Hydrocephalus diagnosed but treatment is considered unnecessary as it is said to have spontaneously arrested and others are not diagnosed but are found on scans taken in

later life to have ventricular dilatation.
Hammock et al.(1976) suggest that despite normal cerebrospinal fluid pressure, stable head size and non-progressive neurological symptoms, it cannot be assumed that an arrested state of Hydrocephalus exists. Normal Pressure Hydrocephalus may be present and should be suspected in those children who fail to demonstrate continuing psychomotor development with advancing age. This could be one of the reasons behind conflicting findings regarding children with and without Hydrocephalus and is worth bearing in mind.
Milhorat(1972) states that many cases of 'arrested' Hydrocephalus are in fact Normal Pressure Hydrocephalus.
Soare and Raimondi(1977) do not consider that arrested Hydrocephalus is a non-pathogenic process and if their patients show evidence of Hydrocephalus they are shunted early in life. Spain(1974) found that at least half of her sample without shunts showed some signs of non-progressive Hydrocephalus. She stated that in this group it would be unwise to assume that their abilities had not been affected by pathology of some kind.
Stating that children have Hydrocephalus is most commonly done when a shunt has been inserted(Anderson and Spain 1977), but although in a sample such as that of Soare and Raimondi (1977) this will be a good guide, in many pieces of research there must be considerable doubt over the state of the Hydrocephalus in those said to be 'arrested'.
One of the early pieces of research, that of Badell-Ribera et al.(1966), studied 75 children with Spina Bifida 62% of whom were said to have arrested Hydrocephalus. They suggested that this untreated group showed the natural history of the condition but as it was drawn from a rehabilitation centre it is likely that any very severe cases would be missing. They found that the children without Hydrocephalus had higher overall IQs and that those with Hydrocephalus had a significant difference between their verbal and performance scores. Bearing in mind the views of Milhorat(1972) and Soare and Raimondi(1977) the findings from this research need to be viewed very tentatively and as has already been mentioned, Tew and Laurence(1972), who also studied conservatively treated children, had very different findings.

They did not find significant differences between verbal and performance scores.
A distinction rarely made in research, presumably due to lack of the relevant data, is that between communicating and non-communicating Hydrocephalus. This is presented in a very confusing manner by Hemmer and Bohm(1976) who talk of children with communicating Hydrocephalus or Hydrocephalus associated with Myelomeningocele, in their research into the removal of shunts. They do not make clear what type of Hydrocephalus is present in their Myelomeningoceles. Tromp et al.(1979,1982) and Tromp(1984)separate their samples into communicating and non-communicating Hydrocephalus . Tromp et al.(1979) and Tromp(1984) also consider samples with Hydrocephalus caused by trauma or infection, alongside their Spina Bifida sample.
Whether the Hydrocephalus is communicating would appear to be of major importance in the development of intelligence. Tromp et al.(1979) quote a mean of 72.2 for a sample of 39 children with non-communicating Hydrocephalus compared to 94.3 for 16 children with communicating Hydrocephalus. Tromp et al.(1982) found that children with non-communicating Hydrocephalus had a more severe memory impairment than those with the communicating type, although both were significantly poorer than the controls. They were unable to account for this deficit purely on grounds of low intelligence, so point out that this must be considered an extra impairment. Those with Hydrocephalus differed more markedly from the controls with respect to longer term retention than with respect to verbal intelligence. The marked deterioration between immediate and delayed trials could not be explained by attentional deficits. They suggest that this provides unexpected information on the nature of the mental impairment associated with Hydrocephalus in that whereas intellectual deficits have been recognised, verbal memory has been thought to be fairly well preserved. This study showed that long term memory for verbal material was quite seriously affected.
The information on the intellectual levels of children with communicating and non-communicating Hydrocephalus adds important information to the more usual shunt/no shunt

distinction where the former group score considerably lower on tests of intelligence. Halliwell et al.(1980) found mean IQs of 80 for children with shunts and 100.1 for those without.

Milhorat(1972) states that the most common congenital lesion causing communicating Hydrocephalus is the Arnold Chiari malformation which occurs in very many of the children with Myelomeningocele. However he also states that it is most often associated with other abnormalities such as aqueductal stenosis which therefore causes non-communicating Hydrocephalus. Thus it could be assumed that the majority of children with Myelomeningocele will have non-communicating Hydrocephalus and in the sample of Tromp et al.(1979) 70% fall into this category. It is most likely that those with the least brain abnormalities will have communicating Hydrocephalus and are probably the least handicapped generally.

Lonton(1982) in his consideration of adverse criteria for the intelligence of Spina Bifida neonates mentions the fact that one such factor could be non-communicating Hydrocephalus although his research does not make the distinction.

Anderson and Spain(1977) distinguish between children with and without shunts and note that those with shunts tend to have impairment of intellectual functioning. Spain(1974) tested six year olds on the WISC and found that only 35% of shunted children had verbal and performance IQs of over 85, which is the lower end of the normal range for this test. Children with shunts and IQs below 80 had significant differences in their verbal and performance scores and she suggested that children who were hyperverbal were likely to be those with poor performance ability. She also reported on the verbal and performance ability of 145 three year old pre-school children. The 96 children with shunt controlled Hydrocephalus showed lower mean scores on all tests but this was particularly marked on the non-verbal tests. Only one third of the children with shunts seemed to be developing normally and the presence of a shunt was also associated with moderate or severe physical handicap. The children with shunts and below average performance scores also tended to show poor verbal scores and 40% of this group were rated as hyperverbal. The tests used were part of the Griffiths Developmental scale for non-verbal skills and parts of the Reynell Developmental Language scale for verbal skills. The mean developmental quotients were as follows:-

	Griffiths		Reynell	
	Hand-eye coordination	Performance	Comprehension	Expression
Shunts	79.2	79.5	89.0	86.6
No shunts	95.3	96.5	109.1	105.7

These results show a considerable verbal/performance discrepancy for both groups but the shunted group are lower all round. Children with Spina Bifida, particularly those with Hydrocephalus, are at risk for upper motor or sensory neurone defects which are likely to affect hand function in addition to contributing to poor mobility(Wallace 1973). The spinal cord is frequently malformed above the level of the neural plaque(Emery and Lendon 1973) and Wallace(1973) comments that neurological defects such as bilateral pyramidal tract dysfunction and cerebellar ataxia are commonly diagnosed when the upper limbs are examined. All of these factors could contribute to the poor development of performance skills which were shown by Spain(1974) to exist at the age of three years.

Tew(1978) studied children with Spina Bifida and Hydrocephalus using the WISC. Those with shunts were found to have a poor intellectual outcome suggesting that shunts may preserve life but not intellect. The children were tested at five and ten years. He also found that those said to have spontaneously arrested Hydrocephalus had signs of intellectual loss and educational retardation. In the light of what Milhorat (1972) and Soare and Raimondi(1977) have to say about a diagnosis of arrested Hydrocephalus being very doubtful, these findings are not surprising.

Tew and Laurence(1975) had very similar findings to these later ones with an interesting finding that children with Spina Bifida and no diagnosed Hydrocephalus were also of below average intelligence. They would have expected this group of children to have less problems.

Additional information was provided on the effects of shunts by

Halliwell et al.(1980) who used the WISC on children at eleven years, who had been studied throughout their lives. They found intellectual ability to be particularly affected in the shunt treated group as did the other researchers mentioned, and they also found an increasingly deleterious effect on intelligence as the number of shunt revisions increased, but felt that this was not necessarily caused by the number of revisions per se. This matter will be considered in more detail later in this chapter. They also found that children who showed signs of Hydrocephalus but were untreated were nearer in intellectual ability to the shunt treated group than those with no signs at all. Menelaus(1980) makes very similar comments based on work with over 900 children in Melbourne over the last 25 years. Young et al.(1973) studied 147 patients with shunt treated Hydrocephalus. He maintains that for those with untreated Hydrocephalus the prognosis for intelligence is unpredictable but for treated children it is much better. He states that prompt treatment of pure Hydrocephalus before six months of age will nearly always result in a child with the potential for relatively unimpaired intelligence, and also suggests that IQ is related to the thickness of the frontal cerebral cortex.

There is a lot of support for his views about early treatment. Raimondi and Soare(1974) found that children shunted before the age of six months were significantly better than those left until later. They confirmed this later (Soare and Raimondi 1977) when they found that 63% of their sample of children with Myelomeningocele and Hydrocephalus had an IQ of above 80 and suggest that it is early shunting which accounts for the comparatively good results. Puri et al.(1977) also found that early shunting resulted in a better prognosis for intelligence.

McNab(1965) states that the thinning of the cerebral cortex does not in itself give rise to impaired intelligence. This occurs if the nerve cells are destroyed by haemorrhage or infection. He comments on the fact that many Hydrocephalic children as they grow older do not seem to be able to initiate thought processes. They are able to acquire a vocabulary and repeat verbal information without understanding. He suggests that this reduction in reasoning power could be caused by the stretching of the association fibres that link up the various areas of the cortex and enable it to function as a whole. These views are shared by Price(1977) who nevertheless admits that these matters are not fully understood even by neurosurgeons such as himself. Hunt and Holmes reiterate the opinions already mentioned that the best indications of later intelligence can be gained from the thickness of the neonatal pallium combined with the sensory level of the lesion. More recent research (Lonton 1979,1983) concludes that this is not a good predictor of intelligence and this matter will be raised again shortly.

Dennis(in Blaw et al.1977)studied 16 Hydrocephalic children with full scale scores of 74 or above on the WISC and concluded that Hydrocephalus retards the development of certain visuo-spatial skills but spares the growth of grammatical understanding. She was unable to explain this completely but from her evidence stated that it was not a simple correlate of the presence of neurological signs usually considered diagnostic of right hemisphere lesions in adults. However she does consider the possible effects of Hydrocephalus on the brain,one of which is that some parts of the cortex are thinner than others due to the pressure acting unevenly within the cerebrum.

One such area is the occipital cortex and she suggests that this may cause problems in the development of visuo-spatial proficiency. She further states that it has been found that the occipital horns of the lateral ventricles are not symmetrical and suggests that the right occipital lobe may be affected more than the left by the pressure in the ventricular system in the early stages of Hydrocephalus.

Dennis et al.(1981) in commenting on the better development of verbal than non verbal intelligence in Hydrocephalics states;-

> The origin of this selective cognitive deficit is in neither the hydrocephalic condition itself nor its treatment, but rather in the developmental brain anomalies and symptoms to which the hydrocephalic child is prone.

Tew(1983) suggests that the fairly consistent pattern of intelligence test scores which he found in shunted children may be due to the fact that the Hydrocephalus causes more damage to the right hemisphere. He found that reasoning, vocabulary, immediate memory and comprehension seemed to be relatively well preserved after ventricular dilatation, whilst performance skills and arithmetic were more affected. This is in agreement with the findings of Dennis(1977). Tew(1983) also found that whereas perceptual-motor and manipulative activities were more or less independent in his control group, they were significantly associated in the Spina Bifida group, particularly those with shunts.
There are two other ways which have already been referred to briefly, in which the presence of shunt treated Hydrocephalus may affect intelligence.
Tew and Laurence(1975) and Dennis(1981) found that shunt revisions did not adversely affect intelligence. Puri et al.(1977) and Halliwell et al.(1980) found the opposite, with there being an increasingly deleterious effect as the number of revisions increased. This was highly significant (P=0.0001). However they did suggest that it is important to know the reason for the revisions as this could explain the contradictory findings. Puri et al.(1977) found that early revision of the shunt, which was normally due to blockage or infection had a more severe effect than later revisions which were normally needed to lengthen the catheter. Infection is a subject considered in more detail by McClone et al.(1982) who subdivided their sample according to whether there had been a history of ventriculitis in the shunt treated children. They found mean IQs of 102 for 39 non-shunted children with myelomeningocele compared to 95 for 86 shunted children with no history of infection, and 72 for 42 shunted children with a history of shunt infections. It was found that in the latter group visuo-motor skills were severely depressed. They concluded that:-

> Mental retardation associated with Myelomeningocele is not an associated trait but rather an acquired deficit primarily related to the onset of ventriculitis and meningitis.

The suggestion is made that better control of infection may improve intellectual status and that the prediction of outcome at birth may be confounded by unforeseen circumstances. It is possible that shunt treated Hydrocephalus is compatible with normal intelligence but post surgical complications lead to intellectual loss. Tromp(1984) confirms that patients with an infected shunt as a complication have lower IQs. He found that the number of revisions did not affect IQ unless infection was present. He suggests that a shunt revision carried out without delay probably does not give rise to further brain damage.

Computerised Axial Tomograms.

Modern techniques are making different types of research possible, one of them being the use of the Computerised Axial Tomograms(CAT-scan) to examine the brains of the children with Spina Bifida and Hydrocephalus. In 1979 Lonton produced extensive research relating intellectual skills as measured on the WISC to ventricle-cortex ratios. The results were studied by grouping the children according to the size of their ventricles, and throw up a number of questions rather than giving definite answers. The main findings were as follows:-

(i) The most normal psychometric profiles were found in the group of children with ventricles in the normal range.

(ii) Children with abnormally large or abnormally small ventricles were worst affected. In those with very large ventricles performances were significantly lower and he suggests that there may be an optimum size for ventricles. The poorest overall profiles were in the group with the mean percentage for ventricles being 62.9% of the brain as opposed to the normal range of 10-20%. Within that group he found those with shunts for Hydrocephalus to be the worst.

Gruber(1983), having reviewed 109 shunt treated patients with Hydrocephalus and related the size of their ventricles to their psychomotor development and frequency of shunt complications, warns that many of the problems of shunt treated Hydrocephalus are likely to occur when the ventricles are of small size. There is a danger of overdrainage in 'successfully' treated cases, especially when standing. To overcome this he suggests that treatment for Hydrocephalus should aim at normal psycho-motor development, freedom from symptoms and a reduced frequency of catheter obstruction rather than being too concerned about ventricular size. He recommends the avoidance of complete reduction of the expanded ventricles.

(iii) Only in the two extreme groups of the six were children with and without shunts significantly different in IQ and reading.

(iv) Reading skill correlates highly with verbal IQ which is relatively unaffected by the degree of Hydrocephalus. There was no significant decline in reading quotient with increasing ventricular size.

(v) The WISC subscale scores most affected by the increase in ventricular size were picture arrangement, block design, coding and object assembly, all of which involve perceptuo-motor skills, whereas digit span and comprehension were least affected. Overall the best areas were comprehension, similarities and vocabulary, suggesting that on the whole these children have a good understanding of words.

(vi) The test mean on the WISC subscales is 10 and every group scored below that for every item on the performance scale and for arithmetic, digit span and information on the verbal scale. This supports the views of Miller and Sethi(1971) who suggested the presence of a specific weakness related to the perceptuo-motor sphere.

He goes on to quote some examples of relatively 'brainless' people of high intelligence(i.e. people with virtually no cortex) and suggests that Lorber's view(1980) that this can be accounted for by a massive overprovision of brain cells, together with high redeployability potential may be the best explanation.

<u>Intelligence related to the extent of the physical handicap and the level of the lesion.</u>

Lorber(1971) stated that although a severely physically handicapped child may be of normal intelligence or above, if he has severe Hydrocephalus requiring a shunt he is likely to be at the lower end of the normal range or below. It is very difficult to separate out the effects of the severity of the handicap and the extent of the lesion from those of Hydrocephalus(Tew1983).

Spain(1974) found that the children who were most retarded mentally were those with a severe physical handicap and a shunt although some such children were in the normal range. Halliwell et al.(1980) found that there was a general decline in intellectual ability with increasing physical handicap. Burns(1966) assessed physical handicap and intellectual capacity(using Stanford-Binet or Merrill-Palmer tests) of children born between 1960-1963 in Liverpool, in order to ascertain the needs for future educational placement. The children were aged two to five years and he assessed one third as being fit for normal school, his criteria being to walk without appliances, have an IQ above 70 and not be incontinent. Half of the children he assessed as needing schooling for the physically handicapped with the remainder being severely subnormal or blind.
Earlier studies tended to be of this more general nature but Badell-Ribera et al.(1966) in addition to carrying out psychometric testing also grouped children according to the level of the lesion. It was found that the higher thoraco-lumbar lesions were associated with more severe sensory-motor defects and Hydrocephalus.
Tew(1978) found that children with thoracic lesions in the T6-T10 range were significantly poorer on all parts of the WISC than those with lesions at a lower level. The greater likelihood of Hydrocephalus being present in the thoracic and thoraco-lumbar lesions may be the reason for this (Milhorat 1972).
Lonton(1977) studied the relationship between intellectual ability and the level of the lesion in some detail as this was of obvious importance in the consideration of the selective non-treatment problem. All of the children had Hydrocephalus and 95% of them had lesions in the lumbar cord which is the last part of the embryonic tube to close. He found that those with higher and more extensive lesions were worse in all respects. They had a thinner cerebral cortex, were more likely to be shunt dependent and heavily physically handicapped, had IQs which tended to be in the subnormal range and low reading ability. This research would suggest that the extent of the lesion is important as well as the level. Those with lumbar-sacral lesions were found to be much less physically handicapped and to have higher intelligence.

In Lonton's 1979 study, as all the children had Hydrocephalus, it provided a rather different sample to many others considered in research. He mentions that children with higher lesions tend to have a greater incidence of Hydrocephalus which could account for the high percentage of higher lesions in his sample.

If information about the level of the lesion, which is obtainable at birth, is of value in determining the prognosis for the child both medically and educationally then research into this aspect is of great importance.

The general index of the level of the lesion is taken as the radiological level but Hunt et al.(1973) consider the sensory level as being of greater prognostic value in both medical and educational terms. They take the sensory level as being the first dermatome of normal sensation above the level of anaesthesia, and found that 66% of the 80 children studied had a sensory level above the upper extent of the radiological level. They may therefore be more severely handicapped than it at first appears.

Most research refers to the radiological level as although no sophisticated apparatus is needed to test for sensory level in the newborn it is not a simple task. Hunt et al. (1973) state that the method of testing preoperatively for sensory level appears crude but is nevertheless effective. The resting baby is pricked with a pin working from the region of the lowest dermatome upwards and the level at which general arousal occurs is noted. It is necessary to exclude spinal reflex movements which occur below the level of the lesion and they stress that experience is needed to do this. They report that when junior doctors did this testing they were very inaccurate as neurological experience is required. This point is also made by Andrews and Elkins(1981) who state that in the young child it is very easy to be misled by reflex movements and they do not recommend the use of this method before the age of six months. Brocklehurst (1976) agrees that accurate assessment of sensory loss cannot be made until the child is at least six months old. He goes on to say that in the newborn, crying in response to pin prick or electrical skin stimulation may give a rough idea of the sensory level.

When sensibility can be more accurately measured Brocklehurst states that it is often found that the areas of normal sensory supply correspond with the level of motor innervation.
Soare and Raimondi(1977) studied 173 children with myelomeningocele,133 of whom had shunt-treated Hydrocephalus. They found that neither sensory level nor external level of the lesion were significantly related to IQ,but within the combined groups of those with and without shunts there was a significant relationship between the two variables together and IQ. Those with both a high lesion and a high sensory level had a low IQ but they suggest that a knowledge of either the external level or the sensory level of the lesion on its own is not a reliable predictor of IQ.

The Attainments of Spina Bifida Children in Basic School Subjects.

Reading.

It is likely that the comparatively good verbal ability of these children helps in the development of reading skills. Their good vocabulary and syntax can help in guessing words in context whereas their visual perceptual problems and ocular defects may adversely affect their reading. Even so, as their auditory skills are rarely affected these can be used to learn to read phonically rather than by look-and-say methods. No sweeping generalisations can be made about the reading ability of these children but researchers have noted certain trends.
Tew and Laurence(1972) found that 37.5% of the children with Myelomeningocele whom they studied were between one and four years retarded in reading compared to 47% of the Meningoceles. This is a finding that the authors could not explain as the latter group tend to be of higher intelligence and far less physically handicapped. They used the Neale Analysis of Reading Ability for their assessment. Tew and Laurence warn against making predictions about expected school progress based on intelligence test results as these can mask a variety of subtle learning difficulties.
Tew and Laurence(1975) studied 56 children using the Vernon reading test and Schonell spelling test. The children were seven years of age. They found that the shunt treated group were the worst with the children without shunts still being poorer than a control group matched for sex, place in family, locality and father's social class. More than 60% of the shunt treated group were unable to read a simple three letter word by the age of seven. Their findings on spelling were very similar.
In 1975 Tew and Laurence found that the results of school attainment tests in reading, spelling and mathematics parallelled the distribution of intelligence but that many of the children were performing below expectation for both age and measured intelligence. In 1983 Tew reported a highly significant correlation(P= 0.001) between WISC full scale IQ and all these attainment tests.

Anderson(1975) found with Spina Bifida children with a mean age of 7.8 years, a group of cerebral palsied children and a control group matched for age, sex and intelligence, that the Spina Bifida children were within a month of their chronological age on the Neale Analysis of Reading whereas the cerebral palsied children were seven months behind and the control group ten months behind. 41% of the Spina Bifida children, 28% of those with cerebral palsy, and only 14% of the non-handicapped group were at or above their chronological age for reading. The mean IQ on the WISC for the control group was 92.7. Whereas in the two handicapped groups the poor readers tended to have low IQs almost half of the non-readers in the control group had IQs of more than 90. The Spina Bifida children tended to have reading accuracy scores higher than their comprehension whereas the reverse was true for those with cerebral palsy. The controls fell somewhere in between. This seems to relate to the verbal ability of Spina Bifida children where they have good vocabulary and syntax but less understanding. The important point in this research is that 41% of the children with Spina Bifida were performing above their chronological age in reading accuracy.
Halliwell et al.(1980) comment that Neale comprehension ages generally lag behind those for accuracy and that reading ages overall tend to fall below chronological age. The suggestion is made that it would be of interest to know if this resulted solely from differences in intelligence or if other factors were involved. Tew and Laurence had to some extent answered this question in 1978 when they noted that many children were not performing up to their expected level based on intelligence and age.
Spelling can also be considered here as it has not been researched to any great extent except in conjunction with reading. Tew and Laurence(1972) found that 72% of the children with Myelomeningocele were between one and four years retarded on the Schonell graded word spelling test. 65% of those with Meningocele likewise fell into this group.

Writing.

Having already mentioned upper limb dysfunction at length, difficulties would be expected to arise in handwriting. The main research in this area has been carried out by Anderson(1976) who studied a group of 29 Spina Bifida children aged 6½-9½ years, and a group of matched controls. The mean Spina Bifida IQ on the WISC was 88 and the controls 92. The study focussed on copying and writing difficulties. Throughout the tests the quality of writing of the Spina Bifida children was poorer than the controls, although odd children could write well. It is worth considering the reasons given by Anderson for the writing problems as the same factors are likely to affect written work in number. She cites four main reasons:-

(i) Receptor efficiency. Many Hydrocephalics have squints which are likely to affect the quality of their vision which may have some effect on their writing although this is unlikely to be the main cause of the problem.

(ii) Sensory organisation. The child must accurately perceive whatever he is to copy and his own written output in order to guide and control his hand and arm movements. If a child is to make sense of and organise the information he receives from his eyes, ears and other senses he needs to be able to explore visual stimuli systematically, to pick out the relevant features correctly and to combine and organise information received simultaneously from various receptors. This may be a problem area. Such things as poor figure-ground perception have already been pointed out (Miller and Sethi 1971, Anderson 1975).

(iii) Lack of muscular control. This may be the main cause of the problem. Wallace(1973) found that 81% of children with Spina Bifida and Hydrocephalus had abnormalities in their central nervous system affecting their control over hand and arm movements. As already mentioned, the majority of children have an associated malformation of the cerebellum and other lower brain stem structures. This is the Arnold Chiari malformation which is likely to affect the control of movement. In addition the Hydrocephalus may cause damage to any part of the cortex. The greatly restricted mobility of the young Spina Bifida child may

limit his ability to develop manual skills.
(iv) Difficulties in organising movement which may be partly caused by confused laterality combined with the lack of muscular control already mentioned.
Anderson and Plewis (1977) add attentional, motivational and emotional problems to the list of possible reasons for handwriting problems. These in fact could be applied to all school subjects.
Halliwell et al.(1980) found that Spina Bifida children who were mildly handicapped and in normal school performed at a lower level than controls in handwriting. This was a group of children of average intelligence and with no complicated history of Hydrocephalus, in whom it would be considered less likely to find such problems.
Other research links with the handwriting problems.
Parsons(1972) gave 59 teenage children with Spina Bifida and Hydrocephalus tests of clerical skill, spatial ability, mechanical comprehension and manual dexterity and found that those with Hydrocephalus were generally inferior in performance to those without but that the latter were below the norm in clerical, spatial and manual dexterity tests. He puts it down to interruptions in their schooling and indirect effects of their physical handicap. This could well be upper limb dysfunction. Both groups did best in the only untimed test, which was mechanical comprehension. It seemed that the understanding was present but the execution of the tasks presented a problem. He concluded that those with Hydrocephalus were poor at visuo-spatial and manipulative skills, which is likely to be a limiting factor in terms of employment.
Tew(1978) agreed with this when he found that Hydrocephalic children were poor at timed tasks and manipulative skills.
Spain(1972) and Sand et al.(1972) found in studying younger children that manipulative tasks were a major problem area and it would seem from the work of Parsons and Tew that they don't grow out of it.

Mathematics.

This is the area of work most frequently commented upon by teachers as causing problems.

Tew and Laurence(1972) found 78% of the children in their South Wales study to be between one and four years retarded in arithmetic(Vernon graded arithmetic test) compared to 37.5% being that far retarded in reading. All the children were Myelomeningoceles. Of the children with Meningocele 65% were retarded to the same extent in arithmetic. In 1978 they found that results of school attainment tests parallelled the distribution of intelligence but that many children were functioning at a lower level than expected based on their age and intelligence.Tew and Laurence(1975) found that one third of the children with Spina Bifida were incapable of simple counting at the age of seven. They also found that the mean mathematics quotient for the group of children with Spina Bifida but without Hydrocephalus was 94.9 compared with the mean for the control group of 105.5. The mean for the shunt treated group was 79.9, with 13 of the 28 children failing to score on the NFER mathematics attainment test. They endorse the view that arithmetic is the weakest school subject for these children and comment that the children with shunts had a shorter concentration span than those without, who were nevertheless poorer than the controls.

Tew and Laurence(1984) found in a group of sixteen year olds with Spina Bifida that both mathematics and reading were significantly poorer than in a control group but that the difference was especially marked in mathematics.

Diller(1969) found children with shunts to be on average two and a half years behind both those without shunts and normal controls in arithmetic.

Spain(1970) studied children using the WPPSI where those with shunts had higher verbal than performance scores, with arithmetic being the weakest area on the verbal scale. She states that in arithmetic spatial ability is needed for success.

Anderson and Spain(1977) make the point that their findings generally indicated that arithmetic is a great weakness of these children and suggest that three out of four of them are likely to have considerable problems which cannot adequately be explained by absences from school and hospitalisation.

The Association for Spina Bifida and Hydrocephalus which is concerned with the practical problems of dealing with these children comments in its booklet for parents on the specific learning difficulties and the uneven development of cognitive functioning. Also mentioned are problems of figure-ground discrimination, motor organisation and the development of laterality, which are similar to the factors mentioned by Anderson(1976) in connection with writing. ASBAH suggests that the children with Hydrocephalus will have the worst problems and that mathematics will present the greatest problems for the following reasons:-

(i) Impoverished pre-school experiences.

(ii) Frequent absences which will interfere with the stepwise progression of number work.

(iii) Distractibility.

(iv) Ocular defects.

(v) Reading and writing difficulties.

(vi) Sensory and motor organisational difficulties.

Gallagher(1977)(Figs.14/15) tested 18 children, mean age nine years one month, in the junior part of a special school for physically handicapped pupils, in reading (Daniels and Diack), visual perception(Frostig) and mathematics (Young group test). The maths quotients were lower than the reading quotients with the means being:- Maths 74.7, reading 79.8 and visual perception 72.8. A higher correlation was found between the scores in maths and visual perception than between those in reading and visual perception. This seems to lend support to Miller and Sethi's(1971)view that a particular area of intelligence is affected to a greater extent in these children even when global intelligence is lower. It seems likely that mathematics which to some extent depends upon visualising relationships spatially, suffers more from this particular deficit in intellectual functioning.

Carr et al.(1981) produced some interesting findings on number work in their study of Spina Bifida children in normal and special schools. They found that given the

Number of children with quotients in certain ranges.

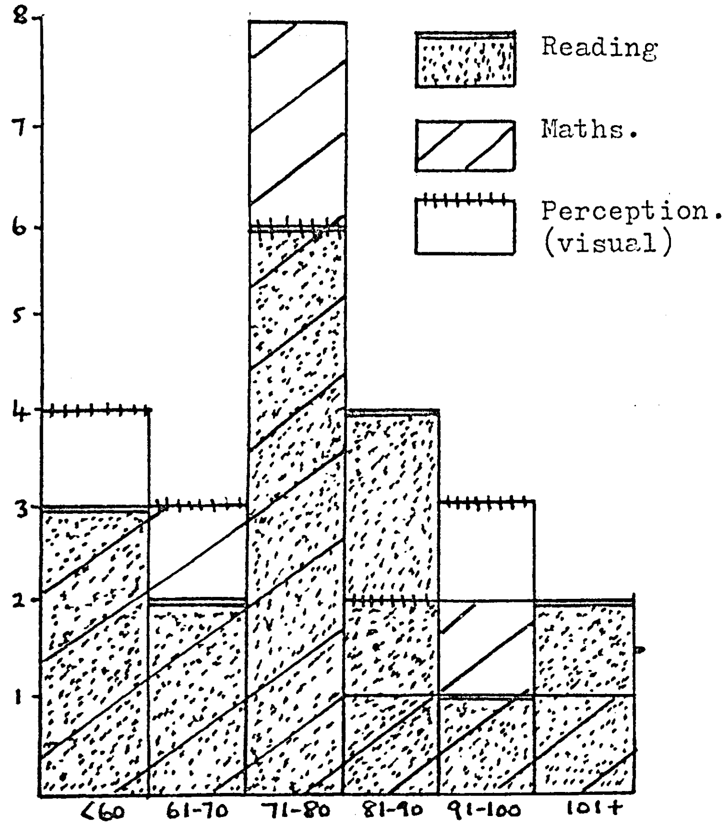


Figure 14.

Reading and Maths. quotients related to chronological age.

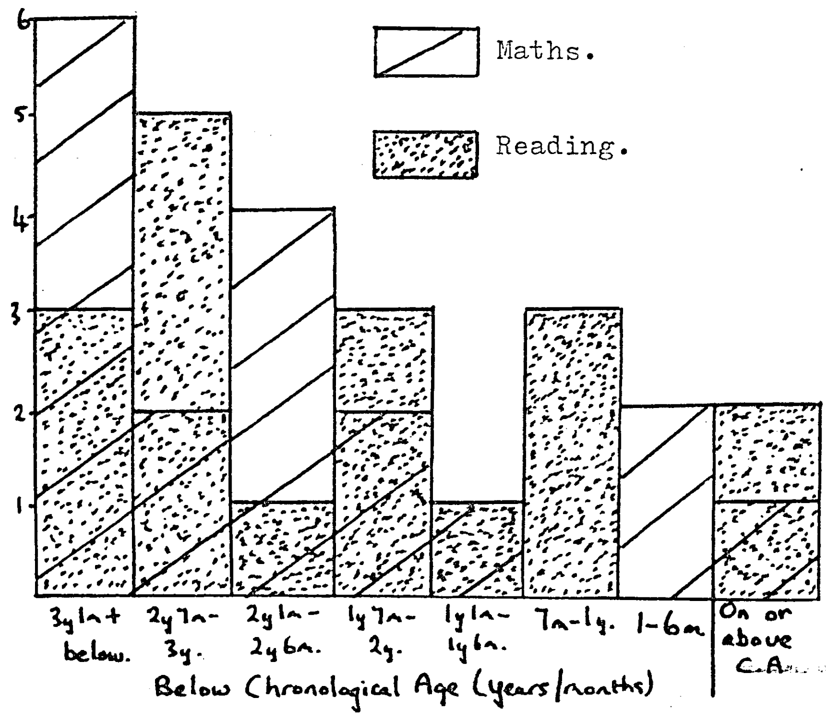


Figure 15.

(Gallagher 1977.)

same level of intelligence the children in normal school performed better in number work than those in special school, but there was no difference in reading ability. They suggested some possible reasons for this:-

(i) The children in special school were more badly handicapped physically and had more problems of incontinence, poor locomotion and shunts. Of these incontinence was not found to relate to reading or number scores (Using the Neale analysis of reading and the Basic Number screening test).

Neither the presence of a shunt or locomotor handicap were associated with reading but their association with number was just significant. Since both these factors could result in the child spending more time in hospital this was considered.

(ii) The number of days off school for hospitalisation between the ages of six and eleven was not related to reading or number, but the number of days off school for hospitalisation before the age of six was significantly related to number but not reading. They suggest that the reasons for this are that restricted mobility in early life among these children may have a particular effect on number work in its early stages and that whilst in hospital a child is likely to have many informal experiences with reading rather than number.

A similar finding was obtained by Soare and Raimondi(1977) regarding perceptuo -motor problems. They found that the children who had spent the least amount of time in hospital before the age of five had the fewest problems in this area. This finding was significant at the 0.01 level whereas a similar finding related to time in hospital before the age of three was only significant at the 0.05 level.

(iii) It is probable that reading is overemphasised in special schools and the atmosphere generally is less academic with lower expectations.

Despite the careful matching for IQ there is still the likelihood that the children in special schools are poorer physically than those in normal school and therefore represent a rather different population. If they have had more time in hospital, as Carr suggests, it may affect their number work more than their reading. This may be because

they will have had less chance to interact with their environment to build up early pre-maths concepts.
Interestingly Tew and Laurence(1978) found that reading ability was significantly poorer among Spina Bifida children in special school than in normal school. They suggested that the greater degree of physical handicap and lower expectations by teachers may help to explain this. This finding is somewhat at variance with that of Carr (1981) mentioned above. Sklayne(1982) found in a comparison of the WISC sub-scale scores for children with Spina Bifida in schools for the physically handicapped and mainstream that the only subscale which was significantly different (P=0.017) was arithmetic with a mean of 10.4 in the PH schools compared to 11.8 in normal schools. The difference in reading quotients was not significant and she concluded that since selection began there was little difference in the academic ability of children regardless of school placement.
Regarding the difference in arithmetic she suggests that the greater degree of physical handicap and level of the incidence of Hydrocephalus in the schools for the physically handicapped, which is likely to result in the children having more absences from school and spending more time in hospital, may have an effect. This is in agreement with Carr et al.(1981) as is her suggestion that the normal school possibly has higher expectations of the children.
She does not make it clear why maths should be affected more than reading by the level of teachers expectations.
She also gives restricted mobility, poor hand control, ocular defects, perceptual problems and distractibility as possible contributory factors to poor results in maths.
It is interesting to consider some related research which has been carried out on other children.
Ayres(1965) carried out a factor analytic study of patterns of perceptuo-motor dysfunction in children. She found that the cognitive functions involved in the development of number concepts were closely associated with perceptuo-motor functions especially within the dysfunction group.
The factor analyses showed that form and space perception and integration of the two sides of the body were very important in the development of number concepts. This is

a similar finding to that of Tew(1983) who found that scores on the Frostig Developmental Test of Visual Perception at five and a half years correlated highly with attainment scores in the children with Spina Bifida but not in the controls.
Lady Jessie Francis Williams(1976) compared children with neurological damage with a control group and found high correlations between the WISC performance IQ and computation. She concluded that visuo-spatial disability at four years of age should be regarded as an indication of possible difficulty in understanding number concepts in later school learning. She particularly studied two children with such problems at pre-school age who still had them at nine years of age, and had specific difficulties in forming number concepts, as opposed to children who had low pre-school copy form tests and showed severe reading retardation later.
Brenner et al.(1967) also studied visuo-motor disability in schoolchildren and concluded that among normal children those who showed the worst problems in this area, but had a normal IQ, had some brain damage. They often showed an adequate school performance in reading but were poor at arithmetic, spelling and writing, were clumsy and had poor motor control.
In recent years two major studies have been carried out dealing specifically with the problems shown by Spina Bifida children in mathematics.
Parfitt(1979) studied the development of number concepts in 130 children with differing degrees of Spina Bifida by using Piagetian tests in basic pre-number and number skills. He also used a battery of other tests consisting of Raven's Coloured Progressive Matrices, Crichton Vocabulary Scale, EPVT, Bender-Gestalt, Burt Graded word reading test and Young Group mathematics test.
He produced the following main findings:-
(i) Children with differing degrees of Spina Bifida and Hydrocephalus pass through the normal stages in the development of number concepts as stated by Piaget although it tends to be at a later age than the normal child.
(ii) The children without shunts were not more successful than those with shunts. He concluded that it may be the presence of Hydrocephalus which is important rather than

shunts. This matter has been fully considered in the section on Hydrocephalus and intelligence.
(iii) The more severely handicapped children became operational on the Piagetian tests later than the less handicapped.
(iv) Boys performed consistently better than girls but were also less handicapped so were not directly comparable.
(v) The Spina Bifida children showed perceptual problems, but caution in the interpretation of the results is expressed due to the motor skills involved in copying. Perceptual problems may affect development of number concepts.
(vi) Spina Bifida children do not continue to acquire vocabulary skills at the same rate as they do in early life.
(vii) The level of reading attainment was below normal at each age level although there was a spurt towards fluency from about thirteen years of age onwards.

His most important finding is the one where he states that the children with Spina Bifida and Hydrocephalus pass through the normal stages in the development of number concepts albeit at a later age. This at least gives hope that these children can develop such concepts in time and seems to provide justification for providing remedial help rather than accepting their seeming inability to grasp mathematical concepts.Early identification of learning problems is crucial so that help can be given.
Gibson(1981) began by using the Essential Mathematics Test (Bental1976) to identify the main problem areas for Spina Bifida children in mathematics. She then narrowed down her area of interest to that of using money and found that 'average' ability non-handicapped children did better on both number and money tests than Spina Bifida children of the same age. The tests used were ones she had devised based on a rank order of difficulty of the items in the Essential Maths test. The samples used were very small being only 17 Spina Bifida children and 12 controls. Since the test which she used as the basis of her study is not a standardised test and the manual provides only sketchy information on its validity the findings must be viewed tentatively. However the conclusions she comes to are not at variance with the general points raised by other

researchers. She reiterates Parfitt(1979) in saying that children with Spina Bifida and Hydrocephalus are part of the normal mathematical population but do have problems with the subject.

Tew(1983) comments on the dearth of investigations into the weakness of Spina Bifida children in mathematics and supports the view that this is their weakest area suggesting a number of possible reasons for this, some of which are listed here:-

(i) A defect in general intelligence. He found high correlations between IQ scores on the WISC, and attainments.

	Spina Bifida	Controls
Reading Accuracy	0.82	0.49
Reading Comprehension	0.88	0.61
Spelling	0.81	0.47
Mathematics	0.84	0.60

(ii) Attentional factors. In maths it is necessary to attend to all the information whereas it is possible to skim over a page in reading and still understand it. Tew demonstrated significant positive relationships between estimated concentration span and mathematical ability which was at a much higher level in the Myelomeningoceles than the controls. He found the intercorrelation to be higher with maths than with any other subject.

The correlation coefficient(r) was found to be 0.81 for the Myelomeningocele group (P=0.001) compared with 0.66 for the Meningocele group(P=0.04).

The subject of attention will be looked at later in relation to this study with the possibility of a 'Freedom from distractibility quotient' being considered(Sattler 1982). Tew's findings would suggest that this may be a major factor.

(iii) Spatial ability. The rate of acquisition of maths concepts may be slowed by spatial difficulties which occur as a result of Hydrocephalus, locomotion problems and restricted environmental experiences. He also found a higher correlation between impaired visual-perception skills and maths than any other academic skill. He suggested that abnormal experiences during the early years appear to influence visuo-motor functions. He consistently found a higher intercorrelation between error scores on the Bender-

Gestalt test and maths scores among the Spina Bifida group which was more significant than that in the controls. The difference was greater than in other attainments. However the Bender results were also inversely related to IQ scores so separation of the two posed problems. On correlational analysis Tew had found that Spina Bifida children had much stronger relationships between their intelligence, attainments, perceptual and motor abilities and estimated concentration span than the controls and he suggests that a general factor, which is probably low intelligence, is the reason for this.

(iv) Severity of disability. Tew found that attainment in maths seemed to be affected by severity of disability more than attainments in other subjects. Impaired movement seemed to have a particularly deleterious effect with a difference significant at the 0.02 level, when the group with unaided walking was compared with the group using appliances for walking. Those with wheelchairs were very significantly lower than those with unaided movement (P= 0.001) and just significantly poorer than those who used appliances(P= 0.05). However this may very well link with the fact that the more severely handicapped physically tend to be of lower intelligence and have more associated problems. Linked with this is the fact that he found a significant difference between the maths scores of the continent and incontinent children(P= 0.01) with mean maths ages at ten years being 9.6 and 8.8 years respectively. He also found that maths was the lowest subscale score for shunted children with a mean scale score of 4.8 for children with shunts compared to 6.8 for those with arrested Hydrocephalus , 9.1 for those with Spina Bifida only and 10.8 for the controls. 89% of the shunted sample were more than two years retarded on maths with no child achieving an age appropriate score. 66% were retarded to this degree in reading accuracy and comprehension and 70% in spelling.

(v) Auditory and visual memory. The good auditory memory of these children, which often includes the ability to recite strings of numbers, may well have led teachers to introduce maths to these children before they showed a readiness to learn perhaps contributing to later task avoidance. Their

visual memory may be poor owing to the perceptual factors already mentioned.
(vi) Interruptions in learning due to hospitalisation may affect maths which is a hierarchical subject(Carr et al. 1981).
(vii) The maths curriculum in a special school may be different to that in mainstream school so that the children in the former do not do so well on standardised tests.
In this study however Tew found that the Spina Bifida children in ordinary schools were a year behind the normal population in maths. Andrews and Elkins(1981) also found that Spina Bifida children in ordinary schools were below average in maths but average in reading.
Andrews and Elkins(1981) produced contradictory findings in that they reported a maths age of 8.3years for shunted children at a mean chronological age of 8.6years and a mean maths age of 7.9years for non-shunted children at the age of 10.1years. However as the mean ages were given for 54 and 31 children respectively and the maths ages are given for only 12 children in each group it highlights one of the problems in their research report. The sub-samples are varying ages and sizes and no tests of significance are used so all that can be gleaned from this report are virtually unsupported generalisations. They do not offer any explanation of their finding that children with shunts in special school are nearer to their chronological age in maths than those without shunts whereas in the normal school they found no difference. This does not fall into line with the research already reported.

There is a tendency in the reported research to agree that on a test of general intelligence such as the WISC the verbal IQ of these children will be better than their performance IQ but there is no agreement on the extent of this difference. Halliwell et al.(1980) found the difference to be very small and not significant whereas Lonton(1979) found a large difference. A particular weakness in visuo-motor skills is suggested and it is necessary to consider why this is so , and if this is the main factor affecting mathematical performance which also shows up in research as being a specific weakness, or whether both are weak because they stem from the same roots. In relation to this matter it will be necessary to consider both neurological and environmental factors.

Chapter 3. - Summary.

A review is given of research into the intellectual development of children with Spina Bifida and their attainments in the basic school subjects. There has been little research carried out dealing specifically with mathematics but what has been traced is considered here. The research shows(e.g. Halliwell 1980) that the distribution of intelligence among these children is not normal but is skewed towards the lower end of the I Q range. When compared with the intelligence scores of siblings (Tew and Laurence 1973) children with Myelomeningocele have been found to be significantly lower and this has been ascribed to maldevelopment of, or damage to, the central nervous system.

The Weschler Intelligence Scale for Children which has both verbal and performance sections is the test most frequently used in the research. It has been found by some researchers such as Lonton(1979) that performance scores are frequently poorer than verbal scores in these children. Others such as Halliwell et al.(1980) have not found such differences. The research that has been carried out into these two areas is considered along with suggestions as to why any discrepancy between verbal and performance scores might occur.

Various problems which may affect educational functioning are suggested by the research and these include poor manual control, poor visual perception, impulsivity, lack of efficient strategy and poor scanning ability.

The effect on intellectual performance of Hydrocephalus, severity of physical handicap and level of lesion are considered. Generally the findings suggest a decline in intellectual ability with increasing physical handicap, and a lower level of intelligence in those with shunt treated Hydrocephalus. Frequently the two go together.

Consideration is given to research into the attainments of these children with reading accuracy coming out as their strongest area, possibly linked to their early verbal ability.

Writing is shown as presenting problems which is not surprising in children with upper limb abnormalities and perceptual problems.

Arithmetic is looked at in more detail as it is the area of schoolwork most frequently seen by teachers as a problem area. This is supported by the research. For instance Tew and Laurence(1972) had found 78% of the children in their study to be between one and four years retarded in arithmetic compared to 37.5% thus far retarded in reading.

Tew and Laurence(1972), Diller(1969) and Spain(1970) all found that children with shunt controlled Hydrocephalus performed at a lower level in arithmetic than those without. More recent studies by Parfitt(1979), Gibson(1981) and Tew (1983) are in agreement with this. Parfitt(1979), however, also found that even these children progressed through the normal stages of early mathematical development, as shown by Piagetian tests, although at a later age.

It is possible that the neurological damage associated with Hydrocephalus has a greater effect on the development of mathematical than verbal functioning and the views of Ayres (1965) and Williams(1976) are considered here as they have direct relevance to this subject.

Various suggestions are quoted as to why mathematics should present such problems. One recent piece of research is included(Carr et al. 1981) in which the number of days of hospitalisation before the age of six years was found to be significantly related to performance in maths but not reading, probably due to the fact that it entailed restricted mobility which prevented the necessary pre-number experiences. At the same time many informal pre-reading and early reading experiences would be available.

Generally the research has found that in these children the performance and number skills are far weaker than the verbal and reading skills. Lack of mobility in the early years is frequently mentioned in connection with these findings. It is also necessary to bear in mind the possibility that the neurological damage associated with Hydrocephalus may play a part in this as well.

CHAPTER FOUR. THE THEORETICAL BACKGROUND RELATED TO THE DEVELOPMENT OF MATHEMATICAL CONCEPTS.

Part 1. A consideration of ideas on perceptual and cognitive development.

A consideration of ideas on perceptual and cognitive development.

There is a lot of literature available concerned with cognitive development and it is not the purpose of this work to give a comprehensive overview of this field. However it is necessary to have some background against which to consider the problems of the child with Spina Bifida and Hydrocephalus and as a basis for this Piaget's ideas are discussed alongside various other views. Although the critisism is made that the stages of development are not as clear cut as one might think from the work of Piaget(Cohen 1983), a very large number of writers such as Lovell(1961) agree fundamentally with him. On the subject of visual perception the ideas of Marianne Frostig are considered and these seem to slot in well with Piagetian theories.

Piaget's stages of development.

It is worth considering Piaget's stages of development generally at first as it is possible to consider some learning problems as a developmental lag rather than a deficit within the child. If this is the case it should be possible to help them to make up this leeway.
Later, consideration will also be given to the views of Epstein(1974,1978, 1979) on brain growth spurts, which lend weight to Piaget's ideas.
Piaget's critics such as Cohen(1983) comment upon the fact that he appeared to design experiments to prove his theories and always had a single explanation for any situation. Bryant(1982) also commented upon the single explanations and the fact that lack of ability within the child at any particular stage was the only reason given for his errors. Bryant does also point out that Piaget had raised some important issues which had provided a starting point for many other theorists and researchers. He further states that it is difficult to pin down a definite point about children's behaviour using the experimental model and that often experimenter's conclusions are found later to be unjustified because of uncontrolled variables.

1) Sensori-motor stage.

Piaget's first stage is that which he calls sensori-motor which lasts from birth to approximately two years old.

Frostig(1968) describes an identical stage. At first the infant is completely undifferentiated from the world around him and his movements are reflex. He progresses from this to a relatively coherent organisation of sensori-motor actions in relation to his environment. This involves simple perceptual and motor adjustments to things and not symbolic representations of them.
In the last six months of this period he will start to make internal, symbolic representations of the sensori-motor problems and will start to work out solutions. At about four to eight months the child develops visually guided behaviour of the hands which makes possible the actions oriented towards external objects and events. This would appear to be a very important part of this stage and will be considered later in relation to hospitalisation and immobility during the sensori-motor period, a matter which has already been touched on briefly.
Frostig considers that at this stage the child explores himself and his world and develops an awareness of both along with the ability to move in space and to move objects. She states that the functions which develop at this stage are a necessary basis for the child's ability to distinguish sights and sounds and to focus attention. The child learns to grasp spatial locations and time sequences and sequential order through the acquisition of movement patterns and expectations concerning the results of his own actions. She also points out that although this stage is very important the fact that a child has obviously missed out at that stage should not be a reason for neglecting activities more suited to the next stage, at an appropriate age, alongside remedial activities for the earlier stage.

2) Pre-operational thought.

The second stage is referred to as pre-operational thought and starts around $1\frac{1}{2}$-2 years lasting until 6 or 7 years. Sensori-motor intelligence is very much related to immediate actions. This next stage involves representational thought .He can recall the past, represent the present and anticipate the future in one brief organised act. At this stage it is possible to think about actions and not simply to perform them. Thinking at this stage is still

very limited with its main characteristics being:-
(i) Egocentricity. The child sees no reason to adapt to the ideas of other people.
(ii) Centration. The child centres on one striking aspect of the situation and ignores others, but reasons based on this one aspect. He only takes in those things which attract his attention and these are often superficial .
(iii) Static immobile thought. He is unable to link a series of thoughts together and considers situations in isolation.
(iv) Lack of equilibrium. Cognitive life is a moment to moment one with no stability.
(v) Action. All ideas are based on mental replication of concrete actions.
(vi) Irreversibility. Because thought is based on concrete events it cannot be reversed.
(vii) Reasoning and concepts. The child forms 'preconcepts' which are based on actions and concrete situations, not schematic and abstract. The child's reasoning is such that he can causally relate anything he chooses and can thus explain everything. He is unable to recognise a stable identity in the midst of contextual change.
Bryant(1974) however, considers that children are capable of using external frameworks and making transitive inferences at this stage of development whereas Piaget claims that this happens at the next stage. Bryant(1974) even found that four year olds could do this in some circumstances and that those that failed often did so as a result of poor short term memory for the information needed in such activities, rather than because they could not understand and use such information.
Donaldson(1978) also took up the point of why children failed on Piagetian tasks and concluded that they often answered the question which they thought they had been asked rather than the one they had been asked. She suggested that children were not as egocentric as Piaget had claimed and were able to reason deductively at an earlier age than he stated. It seems from these two opinions, combined with others such as Bower(1977), who does not consider the newborn baby to be as limited as Piaget suggests, that the Piagetian stages may be less clear cut

than he states although they may still provide a basis upon which to look at children's cognitive development. There are those such as Shayer(1981) who still very much support the idea of Piaget's stages of development and are devising systems of learning based on them.

Frostig puts the period of maximum language development between one and four years, and maximum perceptual development as between $3\frac{1}{2}$ and $7\frac{1}{2}$ years, both of which virtually fall into this preoperational stage. During this stage the child learns to recognise his world without having to manipulate objects. Looking and listening become the main channels for understanding his environment. Frostig places what she calls the higher cognitive abilities between the ages of five and eight and this includes integrative and associative functions. She suggests that the child is no longer limited to thinking about his immediate surroundings but can think abstractly about the past and the future, see relationships, draw inferences and form hypotheses at a simple level. This stage of Frostig's overlaps slightly with Piaget's next stage but fits in well with his suggestions.
White(1965) considers the age period five to seven years as very important in terms of learning and states that from age five a transition is made from animal like to human like learning which is very much associated with the increased influence of language upon learning, a fact very much in agreement with the Russian theorists such as Vygotsky(1974) and with Frostig(1968). Piaget however tends to play down the importance of language. White suggests that information obtained from studies on changes in the five to seven year age period may tell us something about the structure of adult mental processes. Adults may have an 'associative' level laid down early in development which is relatively fast acting and exists as a potential but often inhibited determinant of behaviour. The 'cognitive' layer laid down after this is slower in action and is used if the person is able to inhibit the associative response. This layer has its foundations firmly laid in the five to seven year period. Possibly the children who show forced responsiveness and never seem able to inhibit

their first response have been unable to develop this second layer.

Frostig(1968) suggests that all the visual perceptual abilities necessary for school success have been developed by six to eight years of age, and that during infancy the child learns to understand and adapt to his world through the simultaneous use of his own senses and movement.

Movement has already been mentioned so much that it will be considered later as part of perceptual-motor development, as it seems that the two cannot really be separated.

3) The concrete operations period.

Between the ages of seven and eleven Piaget considers is the concrete operations period. He defines an operation as being any representational act which is an integral part of an organised network of related acts. The child becomes systematic in his cognitive behaviour and produces intercoordinated and coherent systems of actions.

Reversibility is now a core property of their thinking. They become aware that an object is composed of separate parts in the way that a group is composed of its members, and that wholes can be broken down into parts and re-grouped into wholes.

4) The formal operations period.

This stage follows from about eleven years of age onwards. Hypothetical thinking becomes possible and all sorts of possibilities and problems can be considered in the imagination. In the early stages the child is likely to become very egocentric again as he thinks up idealistic schemes to bring reality into line with his own thinking and thus he may well become unpopular with adults.

<u>Phrenoblysis</u>(Special brain and mind growth spurts.Epstein 1974) The research in this area has been linked to the ideas of Piaget by psychologists such as Shayer(1981). However interesting these ideas may appear caution needs to be exercised in considering the theories. The fact that 'mind growth' is the term used makes proof something of a problem as it is a term which can't be defined or quantified. It is also necessary to be aware of the fact that the brain growth referred to means myelination and extra connections and not volume. As has already been mentioned Lorber(1980) has shown that the actual size of the cortex is not always important.

Recent research by Epstein (1978) suggested that the brain followed a highly predictable series of two year growth spurts up to the age of 16,interspersed with two year plateaux when little growth occurs. He states that 85% of all children follow the same pattern with periods of rapid brain growth between the ages 2-4, 6-8, 10-12, and 14-16, with the latter two being slightly earlier for girls and later for boys. At this time there is a rapid increase in mental activity.

Shayer(1981) claims that children's cognitive development goes through four stages that correspond to these brain growth spurts. He further states that these coincide with the developmental stages of Piaget. He suggests therefore that intensive and novel intellectual input should be concentrated into the growth spurt periods. If correct these findings have implications for education generally. Arlin(1975) suggests that there should be a 5th Piagetian stage at about age 15, that of problem finding rather than the earlier problem solving.

Cognitive level matching,the educational model that aims to match teaching to brain growth spurts has begun in one area of Long Island, New York. It will be several years before the project can be evaluated.

It would seem that there are sufficient brain growth spurts for a child who misses out early on to progress

through the Piagetian stages at a later age than usual although this may mean that they never reach the stage of formal operations where abstract reasoning problems can be solved at the highest level. Dasen(1972) suggests that in the most affluent of developed countries less than 100% of adults manifest even the concrete operations stage and only 30% the formal operations stage.
Epstein (1974) mentions that children from disadvantaged homes are unlikely to reach the onset of each Piagetian stage at the normal time and ascribes the failure of most Head-Start programmes in America to the fact that they deal with children of 4-6 years which is a minimal brain growth period, whereas those started at two have proved successful. This theory is also used to explain that the slow cognitive growth in the years 12-14 is not merely due to puberty as is usually suggested, but that it is a period of slow brain growth and therefore not the time to present intellectual challenges. The brain growth referred to does not involve an increase in cells but in myelination and the development of a more extended system of connections, providing a more complex and reliable neural network. Even in the young Spina Bifida child whose brain has suffered from Hydrocephalus early in life it is likely that spurts of brain growth can occur and provide an optimum time for learning as in normal children.
E.E.G. studies provide evidence of stagewise development of the brain. All post-natal brain growth stages are signalled by very marked changes in E.E.G. The onset of Petit Mal is appreciably more likely at the onset of each growth stage (Gibbs& Gibbs, 1952). The formation of substantial numbers of new connections among neurons could well be associated with the creation of new connections aberrant enough to produce the known changes in brain waves and behaviour.

Other views on developmental stages.

An interesting piece of research by Dudek et al.(1969) studied the relationships between Piagetian measures and standard intelligence(W I S C) and motor scales (Lincoln-Ozeretsky). A high relationship was found between the WISC score and Piaget's developmental scales for children aged from five to eight years, and both were found to be equally effective in predicting achievement in the first two grades at school(USA). A significant relationship was also found with the motor scales. Vygotsky(1974) suggested similar intellectual growth periods to those of Piaget and Epstein.

Intellectual development.

Having briefly considered Piaget's stages of development it is useful to consider certain aspects of cognitive development in more detail.

Kagan (1972) criticises the supposition that infants know the world only in terms of sensory impressions and motor activities, which Piaget suggests is the case in the sensori-motor stage. Kagan suggests that experimental evidence shows that the ability to form hypotheses is present in children from around the age of nine months. His experiments demonstrated increased attention to mildly discrepant stimuli towards the end of the first year of life. His explanation for this is that the child tries to mentally transform the discrepant event into the form with which he is familiar, the familiar form being the schema which is a mental representation of the event built up from experience.

Chapman(1974) uses Piaget's developmental ideas to point out the restricted opportunities for sensory-motor stimulation in physically handicapped children, and Morris and London(1976) who support Piaget's view that representational thought begins to develop around age two, say that the child needs an environment that will enable him to extend his world so that he can deal not only with the present but also with the past and the future. They emphasise that development is a cumulative process and that what happens at one stage will influence the direction that development will take at subsequent stages. They had found children from poor homes to have a lag in intellectual development due to lack of stimulation at home.

Although Piaget puts forward stages of intellectual development he does not do this for perceptual development as he does not feel that it develops in stages in the same way. He gives organisation and adaptation as the basic properties of intellectual functioning and subdivides the latter into assimilation and accommodation. Piaget considers intelligence to be the ability to make adaptive choices. The child is an actor upon, rather than a reactor to, its environment, and its intellectual development will be affected by:-

a) Maturation, which is a gradually unfolding genetic process.
b) Physical experience which interacts with genetic effects to abstract the properties of objects.
c) Logico-mathematical experience where he constructs relationships among objects as a result of his actions.
d) Social transmission which is knowledge acquired from others.
e) Equilibration which is the process whereby the previous four items are integrated.

From birth the dominant mental activities move from overt actions in the sensori-motor period to perceptions in the preoperational period and on to intellectual operations in the concrete operations period. To gain knowledge by physical experience, logico-mathematical experience or social transmission the learner must be active.

Vernon (1962) who supports Piagetian views stresses that the building up of logical thinking is primarily perceptual and practical with verbal representation of ideas being secondary. He does accept that verbal representation can facilitate rapid thinking and that thought and language become increasingly interdependant among older children and adults. Vernon is talking of the environment within which the child interacts to develop its cognitive ability. This includes the bio-chemical and physical conditions before and around the time of birth which may affect the development of brain tissue. Particular situations he mentions are maternal stress and inadequate diet both of which can have far reaching effects for the child. As the cause of Spina Bifida is as yet unknown it is possible that whatever causes the condition of Spina Bifida and Hydrocephalus and the associated brain damage that goes with it may have further effects on the child, who may possibly inherit some biochemical or hormonal imbalance from the mother. This area is highly speculative and it is necessary to await the medical experts finding the cause of the condition before a lot of points such as this can be clarified. As has already been mentioned dietary deficiencies (Smithells 1980) are now considered to be a very likely cause and this can also cause a decrease in cell numbers and network complexity in the brain (Epstein 1978).

The development of visual perception.

As has already been mentioned it is unrealistic to try to consider cognition and perception as if they were two completely separate entities but they have been split by many writers on the subjects. Literature on perception shows a variety of opinions as to the definition of the subject area.

Frostig and Piaget.

At first sight Marianne Frostig's ideas of developmental stages of visual perception would seem to be at variance with Piaget's ideas but if both are taken as guidelines rather than as rigid age barriers it can be seen that they have a lot of common ground and fit well together. Frostig considers that sensori-motor training is an essential preliminary to perceptual training and that perceptual training is an essential prerequisite for concept development and academic work. If a child has a lag in the development of visual perception it may well present learning problems in academic subjects. Her training programme will be considered later but it is useful to see what she defines as visual perception:-

> Perception is the ability to recognise stimuli and differentiate among them. This ability includes not only the reception of sensory impressions from the outside world and from ones own body, but the capacity to interpret

> and identify the sensory impressions by correlating them with previous experiences. This recognition and interpretation of stimuli is a process that occurs in the brain, not in the receiving organs such as the eye or the ear.
> (Frostig 1964)

She goes on to point out that almost every activity involves visual perception, especially schoolwork which involves the recognition or reproduction of visual symbols.

There have been a number of critics of the Frostig test and programme on the grounds that the areas it considers cannot be separated and it is possible that the inclusion of her first section, that of hand eye coordination, and the fact that the whole test demands a fair degree of motor control, may lead to results reflecting that problem rather than purely visual perception. Obviously if a child performs badly on the first subtest it will lower his overall score but it may be that most of his attention is taken up by manipulating the pencil on the other parts of the test, leaving little for the task in hand. In fact this sort of problem was considered by Miller and Sethi (1971) and their research suggested that this was not a major problem. If a child is really poor on motor control it is possible to do parts of the test with the child pointing or tracing with the finger rather than using a pencil.

The second Frostig area, that of figure-ground perception, is one in which the children in this study fared very badly. This requires the ability to select from the visual field the object upon which one wishes to focus attention. This becomes the figure. Many of the children considered are stimulus bound and are attracted by irrelevant features of the display. In brain injured people generally this imbalance of the perception of the foreground and background is found and it obviously affects many learning processes.

The third area considered by Frostig is that of perceptual constancy which requires the ability to recognise objects from whatever angle they are presented and to see things as the same despite distance. This requires binocular vision for depth perception.

Position in space is the ability to see an object in relation to oneself and that is dependent on a knowledge of ones own body and links very closely with the final area of spatial relationships, which is the ability to see objects in relation to each other as well as to oneself. This ability develops out of the previous one and links up with figure-ground perception which also involves the perception of relationships. In figure-ground the field is divided into two unequal parts, the prominent figure and the background. In the perception of spatial relationships any number of objects are seen in relation to each other but they all get equal attention. Thus for Frostig, perception is a basic prerequisite for intellectual activity. Piaget would appear to disagree with this and does not consider perceptual development as such in detail. He defines perception as:-

> ..the most direct or immediate knowledge of a present object in the sensorial field. (1956)

He considers it to originate as a subset of sensori-motor activity in infancy which reaches a peak about on a par with the structure of late preoperational thought. This fits in very well with Frostig's ideas. She states that perception evolves from the sensori-motor activity and that all necessary skills are complete by the ages 6-8 years which is the end of Piaget's preoperational period. It may also be the end of the second two year growth spurt for the brain (Epstein 1981). Piaget considers some of the same ideas as Frostig. He dwells quite a lot on the spatial aspects in the sensori-motor stage. He talks of an 'object concept' where an object is known to exist separate from and independently of any activity it is used for, and that it exists and moves in a space common both to it and the subject who observes it. The self is one object among others and has its own space filling properties and its own movement in the common spatial field.
By the age of two the child realises that there is one space in which all objects, himself included, are interrelated. From this he develops the ability to keep

a check on his own movements and his position in relation to other objects as well as the ability to cope with the displacement of external objects, realising that objects generally maintain their size and shape even when moved.

According to Piaget(1954) the child's concept of space will be built up from an awareness of his own body. Gradually the space around him becomes differentiated from the body itself and objects become known by reaching and touching them. Active exploration is necessary to build up spatial relationships. Space representation is the development of intelligence as it works on spatial relationships and is built up through the organisation of actions performed on objects in space, which are at first motor actions and then become internalised actions. Adult representation of space results from the active manipulation of the spatial environment rather than from any immediate reading off of the environment by the perceptual apparatus. Thus objects are 'seen' as together or separated in space, less as a result of visual experience in the past but more as a result of placing objects together and separating them.

Thus Piaget does really consider very similar aspects to Frostig but the difference comes with the fact that Frostig suggests that perceptual development needs to precede intellectual development. Piaget distinguishes between intelligence and perception. Perception is based on encounters within the larger context of a developing sensori-motor intelligence which in fact provides the foundation for later intellectual development.

Piaget sees development as moving from an initially pure perception to involve more cognitive ability, which causes changes in the way the child looks at a figure and thus affects the ensuing perception.

Centration on one part of the figure is a characteristic of young children who look at objects with few fixations. This may give them a distorted view as other relevant features of the object may be ignored. The development of attentional processes is basic to perceptual development as the ability to direct ones attention enables one to become an active perceiver.

Breunen, Ames and Moore (1966) found a change in attention in babies according to the complexity of the stimulus and concluded that attention is directed towards objects of medium complexity for the stage of development of the child.

Gregory (1966) suggests that perception is dynamic and involves searching for the best interpretation of the available data. The data is the sensory information and also knowledge of the other characteristics of objects. Perception is partly innate and partly learned and can adapt to new conditions.

White and Castle(1964) state that the assumptions one makes about the nature of visual input can in some circumstances alter ones perceptions. This influence of past experiences is called the effect of 'set'. They describe perception as being sensory awareness as affected by the person's knowledge, mental set, attitudes, expectations, motivation and general way of thinking. With this sort of definition a separation of perception and cognition is not possible and it seems very difficult to divorce Piaget's sensori-motor intelligence from perception. However Piaget does see perception and cognition as poles on a continuum of cognitive development. It seems reasonable to say that cognitive processes are more advanced than perceptual processes and that the former lead on from the latter. This is the view of the writers already considered.

Wohlwill (1960) relates them on three dimensions. As one proceeds from perception to cognition the amount of redundant information required decreases, the amount of irrelevant information that can be tolerated increases, and the spatial and temporal separation over which the total information in the experiential field can be integrated increases. This results in approximate processes based on perception at first where such things as the judgement of form constancy can be coped with, and then it moves to accurate processes such as mathematical reasoning. Experienced teachers would almost certainly agree with this as anyone who has taught young or backward children uses a lot of repetition of familiar material with small amounts of new material at first , whereas when teaching intelligent senior pupils it is possible to set work which requires them to go to the library and extract the required information from among a host of irrelevant facts.

Bower (1971) also tackles the problem of the relation between perception and cognition. He agrees with Wohlwill and also maintains that cognitive structures have their origins in perceptual processes. Wohlwill quotes several other views on this matter. Piaget's ideas are most closely matched by those of Brunswick who emphasises the differences. He contrasts the machine-like precision of reasoning processes with the more approximate achievement of perception and attributes the decline of perceptual constancy in adolescents to the intervention of cognitive mechanisms, which lessen the need for precise perceptual achievements.

The Gestalt view however fits a model of perception intact to the area of thinking. Koffka (1924) states;

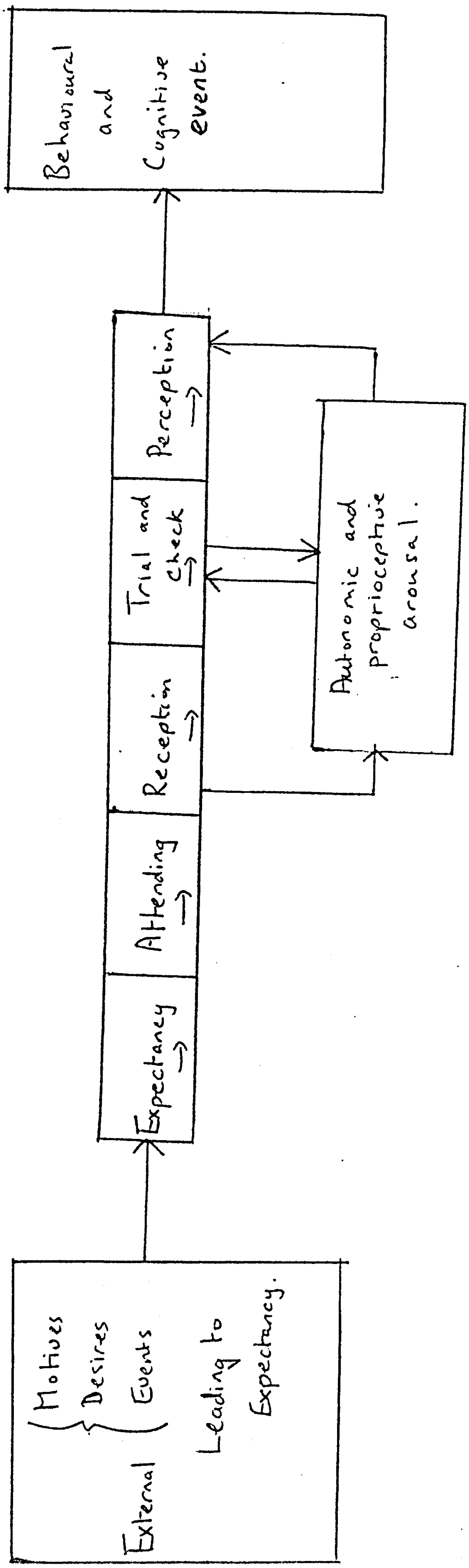
> ..the ideational field depends most intimately upon the sensory, and any means that enable us to become independent of immediate perception are rooted in perception, and in truth only lead us from one perception to another.

Solley and Murphy (1960) summarise the perceptual act diagramatically (Fig.16) and make the important point that people will only perceive if they want to come to grips with the environment, as perception is not a passive process. Arnheim (1970) makes similar points.

Bower (1977) suggests that the development of perception is the development of the ability to process information. Although infants can register single attributes of the visual world they cannot select the relevant ones needed to make sense. The newborn baby lives in a completely perceptual world but his perception is less useful to him than that of an adult because he cannot actively control it. He cannot go out and look for things. The adult does not live in a completely perceptual world as he has memory and knowledge.

Diagramatic schematization of the perceptual act. Fig. 16.

(Solley and Murphy 1960)



Bower found that the infant begins life with the ability to make sense of his perception of people and things and his perceptual world seems to increase in meaning at a rapid rate . Babies under three months saw all parts of a design separately, but after this could attend to a whole. For instance babies under three months saw

as being the same as

The information processing abilities develop partly due to the growth of the nervous system which requires exercise from stimulus inputs for the perceptual system to develop. The nervous system is very susceptible to damage at this stage. If the child suffers from lack of environmental input, structures which are present at birth and ready for development may disappear. Over-stimulation can be just as harmful as the system switches off completely. A variety of developments help to increase the amount of information that can be processed. Habituation involves the construction of an internal schema of any frequently occuring stimulus. This reduces the informational demands of that stimulus and does not take up the attention in the same way that the novel does. During development the child becomes more reliant on knowledge rather than on immediate perceptions, and older children use this to overcome the built in deficiencies of the perceptual system.
Strauss and Lehtinen (1947) suggest that during development perceptual organisation and integration proceeds from primitive and simple to larger and more complex structures , but always with the same characteristics of wholeness and relatedness of parts to parts and figure to background. The more differentiated the nervous system becomes during growth the more details are integrated into the perceptual process, the more articulate are their relationships and the larger and more complex become the wholes which are perceived. They do not think that perception and thinking can be split as the mental process gives meaning and significance to any sensation

and therefore acts as thepreliminary to thinking. On the basis of perceptions and the ability to recall them as images one can work out the solution to a problem, manipulating in the mind the parts and their relationships.

The nature/nurture controversy.

Hebb (1949) stated that perception could not be considered to be either completely innate or completely learned. He suggests that figure ground discrimination is innate which is a view shared by Zuckerman and Roch, (1957) who say that most perceptual learning is in fact perceptual modification. They claim that an infant can differentiate figure from ground,discriminate complex stimulus sources, and attend to parts of his environment; in other words the basic aspects of perceiving are present but need to be built on. This fits in well with Bower's view quoted earlier.Perceptual learning consists of sharpening and differentiating the perceptual acts which are given through maturation and heredity. Neither maturation nor learning can unfold alone and how adults see things depends upon the interaction of nature and nurture within the cultural context.

Whatever views are taken about the relationships between perception and cognition it seems beyond doubt that both are very seriously affected by the child's experiences in the first few years of life.

CHAPTER FOUR. THEORETICAL BACKGROUND.

Part 2. Perceptual-Motor learning.

Perceptual-Motor learning.

It should be obvious from many of the points already mentioned that movement is of vital importance to the early development of the child, and that the Spina Bifida child is likely to have missed out at this stage. It is of value to consider this side of development in more detail as it is possible that it is a major factor in the learning problems shown by these children.
The importance of visual perception has already been mentioned, but this is not enough on its own as it leads to a concentration on only the input side of the human information processing system. A consideration of perceptual-motor learning is far more valuable.
Brenner (1967) in a survey of 8 year olds found that 6.7% had marked visuo-motor difficulties which seemed to affect arithmetic and spelling more than reading. He suggested that deficits in attention, perception and motor control may affect the growth of intelligence which he considered to be a cumulative development arising from the interaction of the individual and the environment.

Theories of Perceptual-Motor learning.

There have been several such theories with three of the most notable being those of Kephart, Getman and Frostig, who all differ slightly in their orientation. They do however agree that motor development precedes and is necessary for perceptual development. Even Getman (1964) who tends to emphasise visual perception has constructed a theoretical model which places the motor before the visual aspects of development. Frostig (1964) leans slightly towards Getman's emphasis on visual perception while Kephart pays more attention to the motor aspects.
Getman suggests that the better the coordination of the body parts and body systems the better the prospects are for developing perception of forms and symbols.
Frostig's views fit in very well with Getman's ideas as she emphasises the necessity for the development of body awareness splitting it into:-

a) Body Image- the child's impression of himself built up from subjective experiences.

b) Body Concept- which develops after (a) and involves

continuous learning about the function of body parts.
c) Body Schema- which is unconscious and variable. This regulates the positions of different muscles and parts of the body in relation to each other, thus enabling the child to carry out coordinated movements and maintain equilibrium.

Other definitions of body awareness vary slightly but the basic ideas are the same.

Kephart(1960) also places emphasis on body awareness as a basis upon which a child can develop complex perceptual motor skills. He needs to understand his own relationships in space and that of the objects around him. Kephart believes that the child needs to develop kinaesthetic figure-ground discrimination first and then move on to develop visual figure-ground discrimination. Kinaesthetic figure-ground discrimination involves the knowledge of the position and possible movement of all the separate body parts combined with an ability to coordinate them to work together. If movement is lacking it is likely that figure-ground discrimination and spatial abilities will be poor. In most able bodied children perceptuo-motor development takes place with no problem but problems seem to occur in many handicapped children. Often these problems are attributed to brain damage but it is useful to put aside ideas on the effect of brain damage and to consider what aspects of the environment of these children are likely to affect their perceptuo-motor development.

Movement is the main aspect under consideration here, and other aspects such as the condition of the mother before and during birth have already been considered.

<u>The importance of movement in the early years of life</u>.

Tatlow(1980) comments when writing about children with cerebral palsy, that their lack of body awareness could be due to passivity and a lack of experience in exploring their own bodies. To a large extent the Spina Bifida child and the cerebral palsied child will have had a similar lack of mobility in early childhood although many Spina Bifida children will have had even less mobility due to the necessity for surgical procedures and hospitalisation. Research findings suggest that both groups have poor visual perceptual abilities (Anderson 1975). Wedell(1972) investigated size constancy in a group of cerebral palsied children aged 7-9 years and in a reference group of non-handicapped children of the same age range. The C P group showed significantly less size constancy at 12 and 17 feet. The analysis for the results for the C P children when they were grouped according to their length of experience of independent mobility, provided some confirmation of the hypothesis that limited experience of independent mobility is associated with reduced size constancy.

All the writers mentioned earlier seem to agree that perceptuo-motor and cognitive development occur or begin during the first two years of life, which must be considered to be a critical time. This is the period in the life of the Spina Bifida child where they will have spent a large amount of time in hospital, usually commencing from birth. At the present time this is less likely to happen due to abortion and selective non-treatment ensuring that only the less handicapped children survive.

Even if a stimulating environment is provided for the child he is immobile and therefore cannot interact. Once the child is home from hospital he may well not be encouraged to be mobile and independent as the parents may understandably be overprotective, or the housing situation may not be helpful in dealing with a handicapped child. In some cases the child will be in no fit state to be allowed to be active. For these reasons the child may miss out on a lot of early play activities. There is also the likelihood of further hospital visits as a result of valve or kidney problems or for further surgery. Mention has already been made of the effects of hospitalisation.

Jan et al.(1977) comment that the motor development of blind babies lags behind the normal and feel that this can affect their intellectual development. Often these babies are reported as being good and undemanding, in other words 'passive'. It is possible that this sensory-motor passivity may lead into a generalised personality characteristic, which is a habitual, learned helplessness. This sort of comment could well be applied to the typical severely handicapped Spina Bifida child who tends to be thoroughly apathetic. This could develop from the long enforced periods of idleness in early life. White and Castle (1964) found experimentally that increased visual attentiveness combined with increased mobility in an enriched environment constituted the optimal circumstances for visuo-motor development. He had studied children in institutions.

Field (1970) in a book written for the parents of Spina Bifida children points out that movement is very important to early development. Without movement, combined with exploration and feeling for space the child may encounter spatial problems in later schoolwork. This is very similar to Frostig's views, but these ideas are not new. Rousseau in Emile stated:-
(1911)

> To learn to think, therefore, we should exercise our limbs, and our organs, which are the instruments of our intelligence.

Tatlow (1980) agrees that movement and the development of space orientation cannot be separated. This view is shared by the paramedical services dealing with physically handicapped children who have missed out on early movement. They all, like Tatlow who is a physiotherapist, lay great stress on the development of spatial abilities and visual perception, generally by means of gross, fine and perceptual-motor work.

Re-afference.

It could be argued that if the child is carried or wheeled around at home so that a different set of stimuli are regularly visible that this should help perception. However Field's views are supported by Held and Bossom (1961) and Held and Hein(1963) whose findings suggest that self produced movement is essential for visuo-motor development.

> We can apply the theory that reafferent stimulation is the source of ordered contact with the environment, which is responsible for both the stability, under typical conditions, and the adaptability to certain atypical conditions of visual spatial performances. (Held&Bossom 1961)

This links up with Kephart's (1960) idea of the perceptual motor match, where there needs to be a correlation between the incoming perceptual data and the outgoing responses. Perception, which can be faulty, can be corrected by the brain, based on previous knowledge, in order to make the match. Held has suggested that if active exploration does not occur the distortion of perceptual data remains and the child's behaviour is at the mercy of such distortions. He develops in two separate worlds which are not integrated, in one he sees, hears and experiences perceptually and in the other he moves and responds. If the two do not fit together the child is likely to have learning problems. Active perception entails stimulation from the environment as well as stimulation from the actions and reactions of the person involved (feedback). Ayres(1965) supports this view.

It would seem that the opportunity that movement affords for interaction with the environment is an essential ingredient of early childhood development and that if a child misses out on it in the very early stages it needs fitting in as soon as possible, and even then there is always likely to be a lag.

Piaget believed that it was necessary for the schemata which would normally be developed at each stage to be developed before moving on to the next. This would certainly seem to be a feasible idea with severely handicapped children such as those with Spina Bifida, who have missed sensori-motor experiences. If a child interacts with things around him he becomes aware both of himself as an entity and in relation to other objects and is able to move to find more stimulation when he is ready for it. A child who is immobile is likely to habituate to those things he can see or touch from his lying position. It is also worth remembering that an individual needs to want to come to terms with his environment in order to perceive rather than to just see. It is possible to see but not perceive as Colin Blakemore mentioned in his 1976 Reith lectures when talking about the phenomenon of 'blindsight'.

Different types of perceiver.

Witkin (1962) suggested that people could perceive in two ways. Field independent perceivers can separate the object from the background as they have a relatively articulated impression of body as distinct from its surroundings, and of parts of the body as being separate but interrelated in a clear structure. Field dependent perceivers find this difficult and are slow to isolate particular items. This latter term seems to apply to many of the children under consideration. A child who has been mobile is more likely to have developed a field independent mode of perceiving which is very much related to figure-ground discrimination. If this psychological differentiation has not taken place the child may well have problems with figure-ground perception. This may also be related to the building up of a body concept, spatial awareness and concepts such as back/front or left/right, very much along the lines of Kephart's kinaesthetic figure-ground discrimination mentioned earlier. Similarly concepts of size develop. If the child is immobile the shapes of stationary objects will not change, and there is no need to conceptualise them in three dimensions, thus the child will not recognise the object if it is moved to a different angle. If the child is always in roughly the same position in relation to an object so that the distance does not vary it is difficult for concepts of size invariance to be built up. In the absence of a concept of size such things as judgement of distance based on size can not be made, so problems will arise in such tasks as aiming or catching in games. Wedell's(1972) findings on size constancy in cerebral palsied children who lacked early mobility also bear this out.

Witkin suggested that girls were more likely to be field dependent than boys which fits in with ideas that boys have better spatial concepts and are more mathematically inclined than girls. Sex differences will be considered in more detail later as there is reason to suspect that intellectually the majority of Spina Bifida children show feminine tendencies based on the general stereotypes used for boys and girls. This could be caused by the lack of opportunities for active exploration, whereas in a culture such as ours normal boys are probably encouraged to be far more adventurous than girls.

Body Image.

From testing carried out on the Spina Bifida children in one school for physically handicapped children(those considered in this research) it was found that the visual perception items of figure-ground and spatial relationships present particular problems. From the Draw-a-Man test they appear to have a poorly developed body image. It is interesting that in the main group of nine children studied their performances on the Draw a Man test were better than usual. This is a group of children who all started in the school at nursery level and seem far more lively than the other Spina Bifida groups higher up the school, where in no case has a whole year group come right through from the nursery. When the case studies are considered some of these tests are included along with some done by children of the same age in a normal school and in an E S N (M) school for comparison.

In the building up of the body image it would be expected that the head and the hands would be the first to be noticed because these areas have large areas of sensory cortex. In Spina Bifida children with cerebellar damage and neurological abnormalities of the upper limbs the feeling from the hands may not be normal , and in children paralysed from the waist down there will be no feeling in this area. Obviously these facts must affect the developing of a body image; it is difficult to be aware fully of a part that can't be felt or used. Kinaesthetic figure-ground discrimination will be similarly affected. Even if movement is encouraged, coordination and balance problems may affect the building up of body image from the spatial point of view, and it is interesting to consider that if a child is moving around the floor, without the use of his legs , he will be using his arms and hands for movement and balance rather than for exploration in the way a normal child would be using them. This could also affect the development of manipulative skills later.

Selective attention.

This leads on to another difference between the child who is mobile and the child who is immobile in the early years. It is impossible for the sensory system to assimilate every stimulus present in the environment. The child who is immobile has no way of interacting with the environment and therefore no reason for paying more attention to one aspect of the environment rather than another. Thus they may fail to develop the skill of selective attention, which is an essential aspect of early perception when the child tries to recognise and differentiate objects. By the third month of life the normal child can decrease his attention to those stable aspects of his environment whilst increasing his attention to the novel. Those things to which the child turns his attention are perceived more clearly and form the figure in the perceptual field, with the majority of stimuli forming the ground. It is impossible to actually perceive an object unless it is in relation to its ground. This may be one of the factors affecting figure-ground discrimination development in Spina Bifida children and may also account for their distractibility and forced responsiveness where they respond equally to any stimuli. This creates a vicious circle because responding to irrelevant stimuli causes excess 'noise' in the cortex and therefore precludes reaction to the relevant stimuli. Many writers stress the necessity for the child to learn to focus his attention in order to learn. Gibson (1960) and Wohlwill (1960) both emphasise this point and Neisser (1967) suggested that attention could be considered in two stages. The first is the pre-attentive stage which is a process whereby a global representation of an object is selected for further refined focal attention, followed by focal attention where more exacting analysis and synthesis takes place. This corresponds to the idea of psychological differentiation which leads from a global representation of oneself and the environment to an analysis and synthesis. Werner and Strauss (1940) and Cruikshank (1966) found that some brain damaged children appeared to have impaired pre-attentive abilities and made a large percentage of

responses to background in a figure-ground test.
Thus it would seem that when teaching these children the training of attention which can be classed as a skill in its own right, and the provision of opportunities for movement must be considered.
Stark(1976), a consultant paediatrician, states that in order to avoid secondary handicaps caused by environmental deprivation, the physically handicapped child must be helped to move around on his own and to explore his surroundings.

The importance of movement has been strongly emphasised in this section. It is useful here to refer back to the work on the development of the brain and remember that it was mentioned there that activity was necessary to develop connections and ensure that the brain functioned as well as possible. Linking this to the ideas that interaction with the environment is necessary to develop perceptual skills of all types merely serves to emphasise the importance of movement in the early years of life and the necessity to start any compensatory programmes as early as possible. Ayres(1965) suggests that movement produces sensations from the skin, muscles and joints. The movement receptors of the body have a distribution to the cerebral cortex and brain stem both of which are involved with sensory integration which is necessary for learning many skills. Neurophysiologists seem to accept that movement stimulates the ascending reticular activating system which stimulates the cerebral cortex so this would help to prepare the brain for learning. If learning is dependent upon perception and perceptions are dependent upon previous motor experience then learning is ultimately dependent upon motor activity. However it is dangerous to make a simple direct link between motor development and conceptual learning because in many cases any link may be indirect. For instance it is possible for a child's learning to improve as a result of improving his confidence and self esteem by improvement of his motor activities, or, as mentioned earlier, the actual development of the brain can be affected by early childhood experiences and can thus affect learning.

Obviously in the context of the children being considered in this study it is necessary to consider a number of viewpoints including neurological and environmental ones before drawing any conclusions. Even having done that conclusions are likely to be tentative ones as there are always uncontrollable variables involved.

CHAPTER FOUR. THEORETICAL BACKGROUND.

Part 3. The development of mathematical concepts.

The Development of Mathematical Concepts.

Piaget's views on the development of pre-number concepts.

Once again it is of value to consider Piaget's stages of development, this time in relation to pre-number concepts. Much has been written about his ideas and many experiments have been carried out to check his findings, most of which have supported him. Dodwell(1962) however feels that the stages are not as distinct as Piaget would seem to suggest.

Piaget suggests three stages, all of which fit into his overall preoperational period, although stage three overlaps slightly into the concrete operations period. Piaget does not state that certain things will happen at certain ages but that the child will need to pass through the stages mentioned. Both of the first two stages are very much governed by perception and it is only in the final stage that perception comes under control and thinking predominates. Until this stage is reached the child will have very little understanding of mathematical concepts. According to Piaget the construction of number goes hand in hand with the development of logic, and a pre-numerical period corresponds to the pre-logical level. A sequence of numbers results from an operational synthesis of classification and seriation.

Conservation.

Piaget (1941) states that conservation is a necessary prerequisite for any mathematical understanding because a number is only intelligible if it remains identical with itself, whatever the distribution of the units of which it is composed. Bryant(1974) agrees with this statement. Thus conservation in various forms would seem to be a necessary requirement for success in number work. Piaget breaks it down into such things as continuous and discontinuous quantities, number and mass. In all of these in stage one the child sees a change of form in the object or objects and assumes that the quantity has likewise changed. The child is ruled by perception and interprets the change he can see as actual change.

This is followed by a stage where the child finds conflict between his immediate perceptions and his attempts at logical thinking and he begins to think on some occasions that his perceptions are faulty. However this is a changeable situation and not a sufficient basis for sound thought. In stage three the child conserves, but this stage does not occur at the same age for all children or for all aspects of conservation. For instance conservation of number tends to occur six months to a year before the conservation of mass. At stage three the child will realise that quantities remain equivalent even when the space occupied changes, and will be able to cope with the logical multiplication of the relationships of height and width and relationships between objects. His thoughts will include the reversibility of situations. In seriating the child will have moved from a situation where he will have been completely unable to cope with such a task, through being able to complete it by trial and error, on to the final stage of being able to simultaneously coordinate the relationships between all the items to be arranged serially. Piaget's experiments on conservation are probably one of the best known areas of his work and as such have been considered by very many researchers.

In recent years a lot of critisism of these experiments has been produced(Donaldson 1978/82, Bryant 1974/82, Miller 1982) based to a large extent on the general point already made that Piaget had only one explanation for children's behaviour on any task.

Donaldson(1982) suggests that children fail in conservation tasks because they and the experimenter are on different wave lengths and the child is misled into saying there has been a change in quantity by an adult experimenter who seems to want that response. She had been involved with experiments where a naughty teddy was used to rearrange the counters rather than the experimenter and under these conditions more children showed conservation. She feels that the conservation problem is not as simple as Piaget makes out.

Miller(1982) tried similar experiments using accidental transformations and also used natural ones with children moving around. He found that adoption of the more natural form of transformation did not result in significantly better results and stated;

> The fact that they believe that the number of chips changes when an adult spreads them on a table is remarkable but the fact that they believe that the number of other children changes as the children move about is in some ways even more remarkable.

However he did find that on a test like that already mentioned he got significantly better results than on the standard test.

Bryant(1974) suggested that Piaget's experiments were not completely convincing although they did produce very important ideas from which to work. He accepts that children show the type of errors which Piaget suggests in conservation tasks but not that the only reason for the errors is a lack of understanding of invariance. He doubts that the experiments actually showed anything very definite about the young child's understanding of invariance and suggests that successful completion of conservation tasks may depend upon inference as well as an understanding of invariance and feels that this is something which Piaget does not consider in relation to this matter. He further suggests that there are at least three ways of explaining failures in the conservation task in addition to Piaget's view that the child is being ruled by his perceptions. These three are memory failure, a failure to make inferences or a conflict between incompatible judgements, with the latter being the most likely explanation. In this situation he is likely to favour the judgement which is prompted by the most recent display as he does not know how to resolve the conflict.

Bryant(1974) states that two rows of counters can be judged by total length or by one to one correspondence and the young child uses both these cues. He mentions experiments which have been carried out to train children to respond to the correct cue upon which to base their judgements and such children have shown improvements as a result of training. However the situation is rather different when the experiment involves transforming a single quantity and he suggests that it seems that children have two rules which they use in different situations. One rule is that the number is invariant unless something is added or taken away and the other is that if two different rows have different lengths the longer one is usually the more numerous. They do not realise that these rules are inconsistent and therefore have problems in the traditional conservation experiments involving two rows of counters. He admits that he cannot explain how they learn these rules originally or when or how they learn they are inconsistent.

The additive composition of classes.

This is another vital pre-number area mentioned by Piaget. In stage one the child has no idea of class inclusion. This is then followed by the trial and error situation of stage two and leads into stage three where the child can deal with the additive hierarchy of classes. When the child has reached the level of reversible operations he becomes capable of inclusion, seriating and counting and this occurs in stage three.

Field dependence.

During development the child moves from a global to an analytic type of evaluation. Many adults tend to be somewhat global in their methods of approaching problems and it seems to go with them being field dependent. This links up with the point already mentioned that boys are said to be better at maths than girls and also tend to be more field independent.

Further research into Piaget's theories.

Flavell(1970), Phillips(1975), Elkind(1961), Sigel(1966) and Lovell(1961) have all written very much in support of Piaget's theories.

Hood(1962) carried out an experiment to see if a group of normal English speaking children (61 boys, 65 girls aged 4.9-8.7 years) and a group of mentally retarded children and adults(23 ESN and 17 mentally defective) would show the same general trends in the development of pre-number concepts as those suggested by Piaget. He found that even among the ESN level those who had Piaget's pre-number concepts were generally making progress in arithmetic. Among all those studied there was no case of a child with poor Piagetian pre-number concepts succeeding in arithmetic. He concluded that children still at the intuitive stage rather than the concrete operations stage were not ready to do formal arithmetic. Parfitt(1979) in his study of children with Spina Bifida found that they passed through the normal stages of development of mathematical concepts as assessed on Piagetian tests, although this was often at a later age than the normal child.

Gelman and Gallistell(1978).

The ideas of Gelman and Gallistell on the child's understanding of number are interesting as they appear to be rejecting certain of Piaget's ideas and put up convincing arguments for so doing. Before considering their views it is necessary to consider the description of two schools of mathematics teaching which they mention. Firstly the 'practical ' school which focusses on the ability to obtain correct numerical representation of sets.e.g. 13 apples plus 11 apples = 24 apples. Secondly the 'theoretical' school which focusses on the ability to reason about number and to recognise abstract properties when using numbers. e.g. 13 + 11 = 11 + 13 = 24, or (a+b) = (b+a) which is an abstract property known as the commutative property which holds regardless of the actual numerosity represented by the algebraic symbols a and b.

For everyday life the former(computation) is likely to be more important in a lot of situations although on its own it gives little scope. The latter is necessary for mathematical understanding and can be an aid to the former. It is possible to achieve simple computation ability with no understanding at all and most teachers will have done this with a number of children. This is possibly why the views of Gelman and Gallistell appear to be at variance with those of Piaget. Piaget's ideas of pre-number concepts would form a basis for the theoretical or abstract school of mathematics whereas the ideas of Gelman and Gallistell seem to link only to the practical school.

They state that there seems to be little disagreement about the fact that children don't conserve before the age of five but they disagree with Piaget about the necessity for conservation before the development of number concepts. They suggest that children are capable of dealing with numbers long before they pass the conservation test, but conclude that what children lack is the ability to reason about numerical relations.i.e. the ability to reason algebraically as in the theoretical school. This does not really contradict Piaget as children can often manage computation before conservation is achieved but may have no real understanding. They have not reached the level of reversible operations such as is required for an understanding of numbers. Later on they make the point that the counting process is not an intrinsic part of the reasoning about number but provides a basis upon which the reasoning operates. For instance if counting yields identical numbers of items in two sets the sets are judged to satisfy the equivalence relation, the child having reached this conclusion by reasoning based on counting. They suggested that in looking at children's abilities in arithmetic it is necessary to look at both the child's ability to count and the child's ability to reason arithmetically. Such reasoning in the young child should include a set of recognised numerical relations(equivalence and order), a set of operations(addition,subtraction) and a principle of solving for a difference. Initially all these things will depend on counting. They give a series of stages of development of the concept of number, the early ones of which are as follows:-

(i) The development of counting skills and the routinisation of counting constitute one line of development. The children make up their own lists, self correct and spontaneously practice. These behaviours are the same as those found in the early stages of language acquisition.

(ii) The acquisition of count words which also involves knowing the rules for generating counting tags beyond the base series.

(iii) The child's reasoning moves from a dependence on specific representations to an algebraic stage in which such representations are no longer required. In this stage principles of numerical reasoning have accommodated so as to apply to information about relations themselves.

In fact these stages would overlap quite well with those of Piaget, the only disagreement really being the stage that should have been reached in pre-number work before number work should be attempted. This obviously has implications for teaching as to attempt formal 'sums' too early may do more harm than good.

Early Mathematical Experiences.

In 1978 the School's Council produced a set of six booklets, with which additional material was available, called Early Mathematical Experiences(Matthews). The aims of the project were to identify relevant experiences leading to mathematical ideas and then to produce guidelines for teachers to help them to stimulate the development of mathematical concepts. They defined a concept as an idea abstracted from a variety of related and repeated experiences.

In the general guide it is stated that the years from three to six are vital ones in the development of language and mathematical concepts and that the idea of 'sums' for the very young is meaningless.

A lot of pre-number experiences involving comparison, shape and space are required. In consultation with Piaget they produced a 'concept tree' which is also used in the Nuffield Mathematics Project 5-13. The early part of this, up to the end of the concrete operations period, is shown in Figure 17. After the initial starting point of sets and relations this tree has two main branches which lead to arithmetical and algebraic activities respectively. It is the latter which seems to include the 'spatial' activities. It shows very clearly that a lot of activities come before 'sums', such as sorting, matching, comparisons and shape recognition. Similar concepts are mentioned in the Fletcher Mathematics Scheme(1970), and a number of recent maths schemes are also based on this hierarchical development of concepts and quote Piaget's theories(e.g.Duncan 1979).

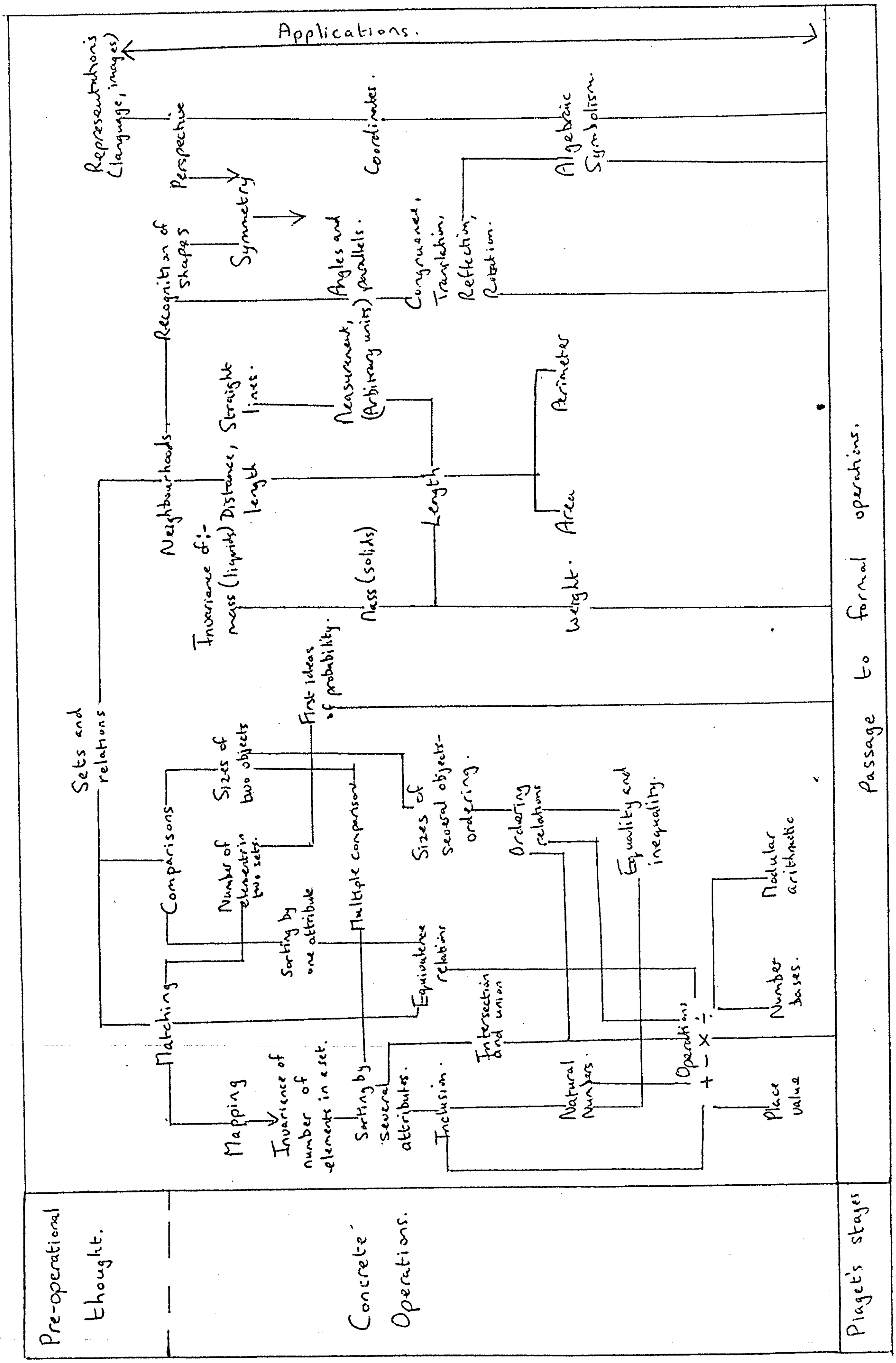
Aileen Duncan Mathematics Scheme.

Duncan(1979) has produced a maths scheme for five to seven year olds based on Piagetian principles. She emphasises the importance of classification, matching and conservation as pre-number activities, and suggests a simple conservation test to be used before written sums are attempted.

The Concept Tree from Early Mathematical Experiences.

Figure 17.

(to end of concrete operations)



Both she and Skemp(1971) agree that strict hierarchical development is not essential and that things can be learnt out of sequence, but that the basics must be completed if more advanced concepts are to be developed later. This can only be done by plenty of experimental and manipulative work.

Many Spina Bifida children are attempting written sums when they have no idea of conservation. They tend to be able to learn by rote easily and can develop what Skemp(1971) refers to as pseudo-counting, where they can go along a row of objects whilst repeating numbers but with no understanding of what they are doing. This may lead teachers to think they are ready to move onto written sums long before they really are.

Skemp's (1971) views on developing mathematical concepts.

Skemp emphasises the fact that mathematical concepts are related in hierarchies, as well as in other ways, and so it is important to consider not only the learning of individual concepts but also their organisation into mental structures of related concepts. Secondary concepts are built on primary concepts and higher order concepts are built on both. He explains what he means by these terms very carefully. 'Dog' is a primary concept, derived from sensory and motor experiences of the outside world, mentally abstracted from all the various different dogs the child has seen. 'Animal' is a secondary concept abstracted from such primary concepts as dogs, cats or any other animals. The concept of animal can be widened by including such perceptually different classes of objects like snakes or spiders. This is still a low order concept being only two steps away from things that can be seen, touched or heard. According to Skemp even primary mathematical concepts are of a much higher order, and these concepts are very much dependent on sensori-motor experiences. This is very much in agreement with the sort of ideas put forward by Piaget and Frostig (1968), who emphasised the importance of this stage of development. Obviously people can continue to add to their sensori-motor experiences and primary concepts throughout life. Even an elementary mathematical concept such as counting is dependent upon no less than 10 lower order secondary concepts. It is necessary to know which lower order concepts are required on which to build the mathematical concept. Early classification plays a very important part in this. For instance the child may recognise a chair and then develop from this to recognising the various types of chair as still having the same name. From this the concept can combine with other similar concepts of other objects to form the concept of furniture.

What is a concept?

Naming an object tends to classify it. Classifying means collecting together experiences on the basis of similarities whereas abstracting is the activity by which we become aware of the similarities. Abstraction

is a lasting mental change based on this; something learnt which enables us to classify, in other words a concept.
The distinction between a concept and its name is important. A concept is an idea; the name of a concept is a sound or a mark on paper connected with it. By the time a concept has been formed the name of the concept has become so closely associated with it that it may be mistaken for the concept itself.
In particular, numbers, which are mathematical concepts, and numerals, which are the names we use for numbers, are widely confused.
In general concepts of a higher order than those which a person already has cannot be communicated to him by a definition but only by collecting together, for him to experience, suitable examples. Skemp states:-

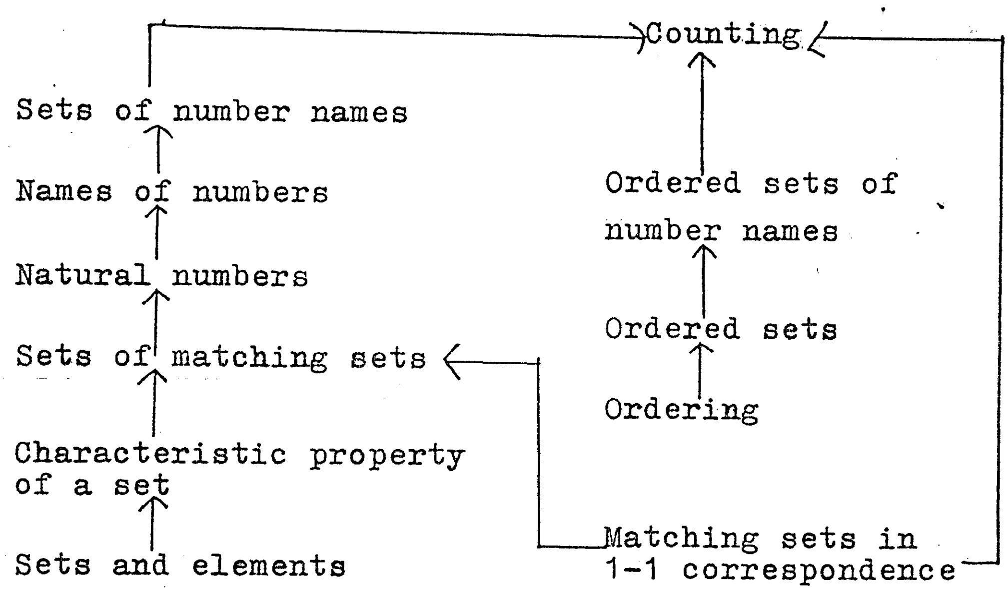
> In mathematics, however, not only are the concepts far more abstract than those of everyday life, but the direction of learning is for the most part in the direction of still greater abstraction.

The criteria for having a concept is not that of being able to say its name but of behaving in a way indicative of classifying new data according to the similarities which go to form the concept.This is possibly where many teachers are caught out. Because a child can use the name of the concept it is assumed that they have grasped the concept, and this can occur particularly with numbers and numerals as mentioned above. Children with Spina Bifida who can pick up the names of things quickly may very easily be assumed to have grasped concepts about which they really know nothing.
Although the lower order concepts can be formed without speech Skemp suggests that speech and language are vital to the development of higher order concepts (Alternative means of verbal communication would serve this purpose equally well),
The power of concepts comes from their ability to combine and relate many different experiences, and classes of experience. It is possible to learn facts but these can

only be used in the circumstances to which they belong whereas concepts can enable explanation and prediction. The human short term memory can only store on average 5-7 words or other symbols. Clearly the higher the order of concepts which these symbols represent the greater the stored experience which they bring to bear. Skemp makes the point that mathematics is the most abstract, and therefore the most powerful of all theoretical systems.

He also suggests that most children learn no mathematics, only the manipulation of symbols having little or no meaning attached, according to a number of rote memorised rules. This is boring and difficult because unconnected rules are harder to remember than an integrated conceptual structure. The real test of whether the child has understanding is when he has to use the concepts, for instance when faced with problem sums where he has to work out just what the question requires him to do.

Skemp(1971) summarises the beginnings of mathematics diagramatically as follows:-



Other views on the development of mathematical concepts.

Other writers on development and visual perception also comment on the development of mathematical concepts and emphasise their abstract nature, and how much they are affected by visual perception.

Schonell (1942) emphasised that arithmetic was a difficult and abstract subject, and writers since that time have agreed. Strauss and Lehtinen (1947) suggested:-

> Accepting the thesis that a perceptual scheme of visuo-spatial organisation is the basis of calculation, it is reasonable to anticipate that an organism whose ability to construct such a perceptual scheme has been disturbed will be hindered in any activities that require its use.

They mention that the development of number concepts depends upon the perceptual experiences derived from the relationships of objects in space, and that the development of a number scheme is a semi-abstract structure evolved from an understanding of relationships of parts to parts and parts to a whole. Processes of differentiation and organisation occur throughout a child's learning of arithmetic. Early responses are made accurately to small or simply organised wholes and diffusely to wholes which cannot be clearly articulated because of their size or complexity. In time the concrete perceptual element of the number concept fades, yielding to the gradual development of a scheme of visual spatial relationships, which seems to form the basis for operations on the abstract level.

Linking visual perception to mathematical concepts.

The points made above are very similar to those made by Frostig and Maslow (1973) when they suggest that because an understanding of visually perceived relationships is essential to mathematics, children with visual perception difficulties will have more problems with mathematics than with reading. They work through several of the areas identified in the Frostig Developmental Test of Visual Perception and explain why each affects mathematical development.

a) Eye-motor coordination.

If a child has problems in this area he may skip an object or count one twice. Adequate eye-hand coordination is necessary for the accurate placement of numerals, and the writing of numbers must be legible, or accurate calculation is impossible.

b) This area can cause a lot of problems. Poor figure-ground perception combined with a tendency to perseverate can result in a child continuing to solve a series of numerical problems in the same way as the first one even if the type of problem has changed. Children with figure-ground problems are particularly handicapped when they begin work with larger numbers containing two or three digits. They tend to lose their place in the step-by-step procedure of working out a problem and have particular problems with regrouping, such as in borrowing and carrying (This is also affected by whether or not the child conserves number), Multiplication and long division sums will cause even greater problems. The most serious aspect of poor figure-ground discrimination is the fact that the child will be inattentive and disorganised. This is not from any desire to be a nuisance but because his attention tends to jump to any stimulus that intrudes upon him, no matter how irrelevant. He is unable to pick out the relevant details from among a mass of information. It is unlikely that any child whose attention wanders will succeed in a subject which is very rigidly sequential as he will never know what step he is up to or where he is on a page.

Inattention among children with Spina Bifida and Hydrocephalus was identified by teachers of these children, in a questionaire completed by Tew (1980) as being the main problem affecting their learning. He suggests that inattention may be due to defects in information processing such as visual perceptual difficulties or limited short-term memory span. The children studied by him who had had multiple valve revisions tended to be less attentive than the others. 45% of the teachers ranked inattention as the main problem with 22% ranking visual perceptual impairment first. As the two seem to be linked it does indicate a very severe potential problem area in terms of learning.

c) The perception of spatial relationships is considered by Frostig as being of most consequence for mathematical learning. Adequate spatial perception is necessary if the numbers on the page are not to look to the child like a wild jumble of marks. When perception of spatial relationships is inadequate the confusion may be so great in trying to understand the chaotic appearing page that no energy is left for dealing with the numbers. Spatial imagery is necessary for perceiving the patterns that are basic to an understanding of the various number systems. Most children on school entry are poor in this area but it develops quickly soon after that age in the normal child. In our number system the placement of a numeral affects its meaning, e.g. 2 can be units, tens, hundreds etc. depending on its position in relation to other digits. For this reason the spatial symbolism is very important.

Kephart (1971) also dwells on the importance of the development of spatial awareness to arithmetical development. As his work has little empirical basis and is heavily couched in jargon it is difficult to assess.

It does never-the-less contain some ideas which are worthy of consideration. He suggests that the development of adequate spatial awareness is the last 'readiness' skill to develop. This is needed in order to cope with a subject such as arithmetic, which is essentially spatial in its nature, and a lack of development in this area may be an important contributary factor in children with specific arithmetic problems. This could apply particularly to the Spina Bifida children under consideration here. As has already been mentioned their lack of mobility in their early years may hinder the development of spatial awareness.

Researchers(Williams 1976, Brenner 1967) have found that children with poor visuo-motor abilities may cope with reading but are generally poor at maths, a fact which is frequently observed by teachers. It is interesting that Goldstein (1939) found that abstracting and categorising abilities were the first to be affected in brain injured adults. They also showed figure-ground confusion and forced responsiveness. All of these are characteristics of many of the children referred to in this study.

The comments made by the Assessment of Performance Unit on monitoring mathematics(1979) describe the subject well.

> Mathematics is concerned with making generalisations about and theoretical models of the real world. It involves looking for patterns and relationships which can be expressed precisely in symbols and it embraces a wide range of important ideas about number and space. Mathematics is essentially a problem solving activity but it is also a unique and powerful form of communication.

Schonell(1942) mentions the following as factors affecting progress in arithmetic. They are very similar to many points already raised.

1) Lack of opportunity to acquire the requisite early number experiences through handling and dealing with concrete situations (pre-school).
2) Commencement of formal or abstract number work before the child has reached a mental level necessary for understanding relationships in an abstract medium.
3) Absence- arithmetic is sequential.
4) It demands a considerable degree of general intelligence to use symbols in an abstract way.
5) Weak memory for numbers. Poor visual imagery.
6) Lack of concentration and attention.
7) Impulsiveness, over-emotional, over-quick, careless child or the opposite; nervous, uncertain and lacking persistence.

Readiness.

Epstein(1978) linking his ideas with those of Piaget would agree to a large extent with what Schonell says.
Although Epstein does not present any of his own empirical evidence, relying on data taken from other studies, the idea of 'readiness' is an important one to consider in relation to maths.'Reading readiness'is a term frequently used,'maths readiness' is rarely heard. Thus although Epstein's grounds for these statements may be shaky the actual point being made is of importance.
He suggests that intellectual input should be most intensive at the brain growth spurt stages, which he has put forward.
Epstein's views were not purely aimed at maths but seem to be very applicable to that subject.

As Schonell(1942) and Skemp(1971) mention, a frequent cause of learning problems in maths is the introduction of written calculation before the child has been adequately prepared.

The ideas in this chapter will link up very closely with later considerations and suggestions on teaching these children and in further consideration of why they have problems with number work.

Chapter 4. - Summary.

A possible theoretical background is provided against which to consider the educational problems of the child with Spina Bifida and Hydrocephalus.
Perceptual and cognitive development is looked at mainly through the ideas of Piaget and Frostig, with other views being mentioned briefly. An interesting area of recent research which links with this ,is that of Epstein(1978) on phrenoblysis, which is also discussed.
Throughout the first section the importance of movement in the early perceptual and cognitive development of the child is stressed and this is followed up in a more detailed consideration of perceptual-motor learning.
The theories of Kephart, Getman and Frostig are mentioned.
How early movement affects the development of the child is considered in some detail with the importance of reafference being mentioned.
Field dependence/independence, body image and selective attention are all considered in this section.
Finally links are made between the importance of movement and the earlier chapter on the development of the brain, where it was mentioned that activity is necessary to develop connections and ensure that the brain functions as well as possible. Thus it would seem that movement is vital for the development of the brain and for the development of perceptual and cognitive skills.
As a basis for consideration of the problems which children with Spina Bifida show in mathematics the development of mathematical concepts is looked at here.
Piaget's views on the development of pre-number concepts are looked at along with other peoples views based on research using his ideas. The points are made that a sequence of numbers results from an operational synthesis of classification and seriation and that conservation is a necessary prerequisite for any mathematical understanding. The work of Gelman and Gallistel(1978) is discussed as it differs to some extent from that of Piaget, although there is a lot of common ground.

The 1978 Schools Council booklets, Early Mathematical Experiences, and the Aileen Duncan mathematics scheme (1979) are mentioned here as examples of the modern schemes where a hierarchical development of basic concepts is stressed to develop a scheme based on Piagetian principles.This is to avoid basing higher level concepts on pseudocounting (Skemp 1971). Skemp's ideas on the development of primary and secondary concepts is considered and the distinction is made between a concept and its name.

The link is made between problems in visual perception and problems in the development of mathematical concepts, with the areas of hand-eye coordination, figure-ground discrimination and spatial awareness all being considered. This inevitably links back to the previous section on the importance of movement to early development.

CHAPTER FIVE.

OTHER FACTORS WHICH MAY AFFECT THE MATHEMATICAL DEVELOPMENT OF CHILDREN WITH SPINA BIFIDA.

Other factors which may affect the mathematical development of children with Spina Bifida.

In the previous chapters a lot of points have been made about factors which may affect the cognitive development of the child. It is of value to expand on some of those which have so far only been glossed over.

Pre-school experiences.

The normal child starts to interact physically with the world around him, very early on in life, playing with toys hung above his pram, crawling around on the floor, and eventually walking, climbing and running around. Even before he can walk he can crawl to an interesting object and then sit and play with it. This is the early stage of learning manipulative skills, when the child finds that by using his hands he can make objects do something. By seeing interesting objects and crawling towards them he can establish whether or not they are within reach and whether or not they really are of interest. Harris(in Elliott and Salkind 1975) suggests that early cognitive development is the development of spatial knowledge which is a knowledge of the layout of the world. This is developed by moving around in that world. In addition to this he will be hearing parents, siblings and others talking to him, often in relation to his activities, even if it is only shouting at him for touching something he should not touch. This helps in language development as well.

The Spina Bifida child even if not very severely handicapped is likely to spend a lot of his early life in hospital or lying recovering from surgery which is not the ideal position from which to explore the environment. During this spell it is possible that they learn to be passive and that this then continues throughout the rest of their lives, unless action is taken to prevent it, leading to the personality characteristics of lack of initiative and motivation, and apathy, as mentioned by Brocklehurst (1976).

If the handicapped child is the first child in the family it is very likely that the parents will be overprotective and the child will not be encouraged to explore even if he shows signs of wanting to. Parents are understandably scared of a child with paralysed legs breaking them unknowingly as can easily happen, and there are so many other problems in early life that play activities may be neglected even when they are possible. When the Spina Bifida child does start moving around on the floor it is usually necessary to use the arms for propulsion and then to use at least one as a prop with which to maintain balance when sitting. This means that early practice of manipulative skills is reduced considerably and this exacerbates the problems caused by the neurological abnormalities of the upper limbs as a result of the Arnold Chiari malformation and other neurological damage (Wallace 1973).

Minns et al.(1977) mention the signs of delayed maturation in Spina Bifida children in terms of the functions of upper limbs but suggest that they may never catch up. As has already been mentioned handedness develops later than usual (Lonton 1976).

The lack of movement and interaction(both gross and fine) may lead to perceptual problems which are added to by squints which occur in many of these children. Due to the urgency of other surgery squints are often not corrected early in life and it is suggested by Brierley (1976) that the effects of abnormal vision before the age of three are irreversible.

If as is suggested by Gallagher (1977) visual perception has a greater relationship to the development of mathematical concepts than to reading then this could be an important point. Spain(1970) stated that in arithmetic spatial ability is needed for success.

Wedell (1973) considers that disturbances of input functions are more handicapping than those of output functioning since they are likely to distort the information on which the child builds up his concepts of the world around him. Active perception entails stimulation from the environment via the senses as well as stimulation from the actions and reactions of the subject (reafference), The child with Spina Bifida is likely to experience

problems from all these angles.
Verbal skills. These children rarely have any auditory problems and seem to develop auditory skills at least as early and sometimes earlier than normal children (Spain 1974), In research into verbal abilities they tend to show up well in some respects at an early age although some are hyperverbal. Spain (1972) found that many children with shunt treated Hydrocephalus and severe physical handicap had good vocabulary and syntax but a poor ability to use language expressively. Other research in this area has been discussed under verbal skills in Chapter 3. Suffice it to say at this stage that the children tend to be good at picking up vocabulary and learning by rote and this can give an impression of brightness and understanding at an early age which can be misleading. It is likely that these children are talked to a lot in early childhood and once speech has developed find that they gain a lot of attention from their chattering (this subject will be considered again a little later), It is likely that their knowledge of vocabulary and syntax is of value in learning to read. Gulliford (1969) comments that emotional stability is necessary for mathematical achievement. He mentions that it has been found that overprotected children(and many Spina Bifida children would fall into that category) tend to be good at English, especially reading, but poor at arithmetic. He suggests that their higher verbal achievements seem to be associated to their constant adult company and lack of normal activity and contact with peers. They also tend to spend time in solitary pursuits such as reading. Lacking the normal activities of play and going shopping they lack much of the incidental experience providing readiness for arithmetic. Possibly once their superiority in verbal subjects is established and they feel secure in this area they develop avoidance and anxiety about maths. Although Gulliford is not talking about children with Spina Bifida his points could well apply to them.
The impoverished pre-school experiences of the child with Spina Bifida may well affect his learning ability at school

and the use of nursery schools and playgroups can help to remedy this by giving the child the chance to function among his peer group in a stimulating environment.

Pre-number and early munber work at school.

Despite having missed out on many early experiences at home the Spina Bifida child may well be sociable and talkative when he first attends school. His school attendance may be punctuated by absences caused by hospital admissions or infections of various types. It has been suggested by the Association for Spina Bifida and Hydrocephalus that one of the reasons for problems with number work is that it is sequential and therefore being absent and missing a step can have a serious effect. Anderson and Spain (1977) feel that the problem is too great and too general to be caused by this alone. It would seem reasonable to suggest that one of the reasons given by Schonell (1942) and echoed by Skemp (1971) and Duncan (1978) is likely to be at the heart of the problem. That is that the commencement of formal or abstract number work, before the child has reached a mental level necessary for understanding relationships in an abstract medium, is a major cause of failure in maths. This could occur with any children but it seems that there is one special reason why Spina Bifida children may be particularly at risk in this respect. Most of the children are good at rote learning and are likely to learn the number names fairly quickly and give the appearance of being able to count. This may result in them being pushed onto formal written sums too early where to some extent they can learn to cope mechanically but have problems later as they have no basis for problem solving. Having missed out on early pre-school experiences they may miss out on essential pre-number experiences at school because they give the superficial appearance of being ready to move on. Teachers may well look at them in their early years and think that they are bright and be delighted at their 'counting ability'. This in fact is pseudo-counting (Skemp 1971) where the child can parrot the number names as he moves along a row of objects but really has no concept of number at all. This can be checked by a simple conservation of number test using counters. If the child realises that rearranging a group of counters does not alter the quantity then he is likely to be ready to proceed to formal number work. If not then he needs a lot more pre-number experiences even though his parents may frequently think he should be doing sums. Many teachers succumb to this pressure from parents and allow themselves to be misled by the child's pseudo-counting so that they can move onto work which the parents will accept as maths. The teacher may also not consider that visual-perceptual development is a pre-requisite for number work so unless this area is covered in reading readiness work it may be neglected. The child may be performing well in reading and therefore not spend much time on the pre-reading skills, Visual perceptual training is a useful area through which to train attention which is stated by teachers of these children as being a major problem area (Tew 1980). Distractibility does not help a child in reading but has an even greater effect on number work where it is necessary to keep track of the sequence of events. In addition as has already been mentioned arithmetic has a large spatial element.

The teacher may well feel that as the child appears bright but is already well behind in schoolwork he needs to be pushed on rather than allowed to catch up on early play activities. Thus the early verbal ability of the child with Spina Bifida may well do it a disservice as it tends to disguise their limitations. By the time their problem has been recognised they have fallen even further behind. It is as well to remember the developmental stages of Piaget, particularly the first one of sensori-motor development which can give the child a good basis for later sensory and motor development. This does not mean that it is a good idea to go back completely to this stage to the neglect of the training of perceptual skills, language skills and thought processes (Frostig 1968). With the older child they can be going on side by side.

Carr et al.(1981) found that the performance in number work of Spina Bifida children in normal schools was superior to that of children in special schools. They suggested that it was possible that the general ethos of the special school was not sufficiently academic resulting in the children not being pushed sufficiently in maths. They thought that reading was over emphasised. However, although their groups were matched for age and intelligence those still in the special school were more physically handicapped than the others, and the result of this in terms of hospitalisation and lack of opportunity for pre-number experiences has already been mentioned.

Socialisation.

In order to find out what sort of friendship pattern the children considered in the case studies were involved in at school a sociogram was drawn up for their class. Only seven of the nine children were present when this was done. Of those only three were involved in friendships, two were isolates and two rejectees. Egocentricity was obvious in all the latter four children but was also present to some extent in the others. Taken overall the social relationships within this class,which is likely to be fairly typical of classes in this type of school,would not seem to aid the development of logical thought. This requires social feedback and practice in taking other people's points of view. It is possible that the lack of normal social exchange and thus the lack of necessity for the development of logical thought plays some part in the learning problems of Spina Bifida children. McNab(1965) and Brocklehurst(1976) are among those who have commented on their lack of ability to reason. Maths which requires logical thinking may benefit from the child developing more normally socially. Placement in the neighbourhood school may be particularly beneficial in this respect especially for those children who are less severely handicapped physically and gain an unrealistic idea of their abilities within the special school. This is the type of child referred to by Carr et al.(1981) who were achieving good results in the normal school.

Social learning psychologists(Zimmerman in Sigel et al. 1981) see cognitive development as being highly sensitive to experience,particularly that of a social nature.

Sex differences in mathematics.

As has already been mentioned, little research has been carried out into mathematics and the Spina Bifida child and certainly not enough to try to consider sex differences in detail. However some of the points mentioned regarding why girls are poorer at maths than boys among the normal school population may shed some light on the problem in connection with Spina Bifida children.

The matters under consideration in recent years(1981-2) include whether boys are more genetically predisposed to learning maths than girls or whether the difference is caused by social conditioning.

Kimura(1973) found that males were superior to females in some visual-spatial tasks whereas females tended to have greater verbal fluency than males. Dichotic listening studies suggested that speech lateralization may develop earlier in girls than boys. Brierley(1976) suggests that as the principles of mathematics are learned early in life by experiment and exploration and not by talk the more advanced verbal ability of girls may put them at a disadvantage. This is because they may use language as their main means of finding out about the world whereas boys may actively explore for longer. Although this idea sounds very plausible it must be remembered that Brierley is not reporting on research but is writing for a general audience. However this idea is very similar to that already mentioned regarding the early verbal ability of both Spina Bifida and over-protected children, and the detrimental effect this may have on the development of mathematical thinking. In the case of these children both boys and girls tend to find out about the world verbally due to their lack of opportunities for exploration.

The theory that there is a delay in the development of the left hemisphere in males is also suggested by Geschwind(1984). The left hemisphere is the one to which speech is generally ascribed. He uses this to explain why developmental learning disorders,such as dyslexia, are more frequent in males than females. His hypothesis is that some male factor, possibly testosterone, is responsible for this delay in the development of the left hemisphere.

It may also be possible that in the early years of learning maths at primary school, girls can give the impression that they understand merely by being better verbally than the boys, whereas really the understanding is not there and they lack a solid foundation on which to build. They may be quite happy with rote learning which allows them to use their verbal ability. A study carried out in the U.S.A. in 1980 (Benbow and Stanley) suggested that boys are born to be better on average than girls at mathematics and this caused a considerable outcry. Statistics can prove that girls have poorer examination results than boys in mathematics but this does not solve the problem of whether this is due to genetic or to social or educational factors. These researchers thought that the differences they found in testing children who had had the same educational experiences were so great that they could not be explained by socialisation alone. It may be that Brierley's (1976) views could help to explain this.

Research by Walkerdine and Walden (1981/2) carried out in Great Britain shows that girls do not so much fail at maths as fail to sustain early achievements in the subject. They found that girls seem to be better than boys at maths when in the primary school. They suggest that this can be explained by the fact that primary maths is based more on the kind of things girls are expected to be able to do such as shopping, weighing and measuring, which provide fewer contradictions than the activities used to exemplify maths in the secondary school. In other words it is the abstract side of maths which causes the problems. They were told in many schools that the girls were good at computation because they could follow the rules but they could not make the conceptual leaps necessary for more advanced work. No conclusion was given as to the reasons for the differences in the performances of boys and girls. It could possibly be a combination of social factors and the differences in brain development both of which could affect the learning styles of the children.

A very large number of factors may affect the child's development of mathematical concepts. Many of these will be at work in the children to be considered in the case studies.

Chapter 5. - Summary.

This chapter expands upon some of the points which have been made briefly in earlier chapters about additional factors affecting the cognitive development of the child with Spina Bifida.
Pre-school experiences are mentioned with the effect of lack of movement and interaction being linked to problems of visual perception which are exaccerbated by untreated squints. The point is made that this affects maths more than reading due to the spatial nature of the former and the fact that good early verbal skills can form a basis for the latter.
Pre-number and early number work in school is considered with the suggestion being made that many children are pushed onto formal number work too early. This can happen with any child but the point is made that the Spina Bifida child may be particularly at risk because with their verbal skills and rote learning they may give the appearance of being able to count and of having maths concepts. The teacher may not realise that this is very superficial and may push the child on rather than providing sufficient pre-number experiences to form a good basis for future learning. It is therefore postulated that the good early verbal skills of these children may to some extent be doing them a disservice.
Socialisation and sex differences are discussed with the former being considered to be important for the development of logical thinking. The comment is made that many of the Spina Bifida children are fairly solitary so never really learn to argue logically.
Sex differences in mathematics are looked at with regard to normal children as the findings could link up with some of the problems shown by those with Spina Bifida. For instance it is suggested that girls develop verbal skills earlier than boys and base their early learning on this, whereas boys base their early learning on exploration which aids the development of spatial skills and thus gives them an advantage in maths.
That this may partly be caused by differences in brain

development is also mentioned. It has been suggested that both boys and girls with Spina Bifida tend to be treated more like normal girls in their early life and seem to develop in a similar way.

The chapter concludes by commenting that there are in fact a very large number of factors which may affect the development of mathematical concepts in the normal child and that a number of them will be at work in the case of the Spina Bifida children under consideration.

CHAPTER SIX - RESEARCH FINDINGS.

AN INTRODUCTION TO THE RESEARCH IN THIS STUDY.

An introduction to the research in this study.

This research began as a school based project to examine the problems that the children with Spina Bifida and Hydrocephalus were showing in mathematics. From a study of the theoretical aspects of cognitive and perceptual development and a review of previous research into the intellectual development of these children, a number of variables were highlighted which appeared to have a bearing upon the development of mathematical concepts. These were:-

1) Level of general intelligence.
2) Degree of physical handicap, which includes the following:-
   a) Mobility, including the use of the upper limbs.
   b) Incontinence.
   c) Type, level and extent of the lesion.
   d) Ocular defects.
3) Degree of Hydrocephalus as shown by:-
   a) Presence of shunt.
   b) Ventricle/brain ratio.
   c) Thickness of cortex and head circumference at birth.
4) Hospitalisation in early childhood and impoverished pre-school experiences.

These problems may well result in the child showing certain characteristics which do not help his cognitive development such as:-

a) Poor manual control.
b) Poor visual perception.
c) Distractibility and attentional deficits.
d) Sensory and motor organisational difficulties.
e) Apathy.

Previous research findings suggest that the above factors in various combinations are likely to lead to an uneven development of skills.
Halliwell et al.(1980) found the distribution of intelligence to be skewed towards the lower end of the scale.
Findings generally suggest a decline in intellectual ability with increasing physical handicap, and a lower level of intelligence in those with shunt controlled Hydrocephalus(Lonton 1982).

The previous research into ability in mathematics supported the premise upon which this study was started, which was that these children found the development of number concepts difficult(Parfitt 1979, Tew 1983).
It was therefore decided that the following hypotheses would be investigated using data obtained from small scale school-based research and large scale data available from Sheffield Children's Hospital.

1) Many children with Spina Bifida and Hydrocephalus have great difficulty in developing mathematical concepts.
2) The problems shown by these children in developing mathematical concepts cannot be solely attributed to low general intelligence.
3) Neurological damage associated with the presence of Hydrocephalus is a major cause of difficulty in developing mathematical concepts.
4) The degree of physical handicap in children with Spina Bifida and Hydrocephalus is a major factor in the development of mathematical concepts.

The third and fourth hypotheses were formulated based on the reasoning that if the problems in developing concepts in mathematics were purely the result of neurological abnormalities then children with Congenital Hydrocephalus only should perform at a similar level. If early movement and interaction play a part then those children with Hydrocephalus combined with a lack of mobility would be expected to have more problems in mathematics than those who were ambulant. However it seemed very likely that it would not be possible to separate the variables indicative of neurological damage from those indicative of degree of physical disability therefore a fifth hypothesis was formulated.

5) The problems which children with Spina Bifida and Hydrocephalus have in developing mathematical concepts are caused by the interaction of a number of variables reflecting both their neurological status and their degree of physical disability.

CHAPTER SIX. RESEARCH FINDINGS.

Part 1. Results obtained on the Young Mathematics Test used in a school for physically handicapped children.

Research findings.

Results obtained on the Young Group Mathematics Test used in a school for physically handicapped children.

Testing was carried out using the Young Group Mathematics Test in a school for physically handicapped children which included a large number of children with Spina Bifida and Cerebral Palsy as well as many other handicaps. These results will be considered generally first to show where the children with Spina Bifida fit into the overall pattern of mathematical ability within the school. It is interesting to note that no child with Spina Bifida(even those without diagnosed Hydrocephalus) in the school had ever taken C.S.E.Mathematics, although they had taken other subjects. Testing was carried out on the following groups of children:-

1976 - All the children in the Junior classes and the youngest of the Senior classes(68 children aged 7-12 years).

1977 - All Spina Bifida children in the Junior classes (18 children aged 7-11 years).

1978 - All children in the bottom two Junior classes (25 children aged 7-9 years).

The original testing was not carried out for purposes of research but with a view to studying the extent of the problems in mathematics in order to establish remedial programmes within this subject. Nevertheless it provided a lot of information which set the scene for the later work.

The results obtained from the large scale testing in 1976 confirmed the belief of the teachers within the school that the children with Spina Bifida had a specific learning problem in the area of mathematics and this in fact led into the further work on the subject. Anderson(1973) had found in a study that 78.1% of physically handicapped children with neurological abnormalities(either Cerebral Palsy or Spina Bifida and Hydrocephalus) were rated by their teachers as being of well below average ability in number work, compared to only 29.5% of physically handicapped children without neurological abnormalities and 30.8% of the controls. In this study the findings were similar, with both the children with Spina Bifida and Cerebral Palsy showing more problems than the children with other disabilities where there was no neurological damage. Even so the children with Spina Bifida performed at a lower level than those with Cerebral Palsy.

The Young Group Mathematics Test(1970/1980).

This was the test of mathematics used in all of the school based research. It is a test of mathematical understanding at a simple level which is aimed at children of normal ability up to a chronological age of 8years 6months and at less able children up to 12 years 11 months. The revised standardisation was based on 3175 children aged 6.7-13.1 years,of which 1064 were infants, 613 first year juniors, 650 second year juniors and 848 older backward children. The test is in two parts. There are two oral sections which emphasise the place of language in mathematics and also test the understanding of basic concepts. These are matched by two computation sections, one for addition and one for subtraction, in which a horizontal form of computation is used in the belief that the child's understanding is better demonstrated by his ability to deal with two figure numbers in this way and that the teaching of the skill to do this mentally should precede computation in columns. Ridgeway in Levey and Goldstein(1984) critisises it on the grounds that half of it depends on language and two thirds consists of the four basic rules of number. As this is a test for the early years of mathematical development this may not be a disadvantage,but it is not made clear by Young how the items were chosen for the test.

Young found that the correlation of the oral with the computation sections was 0.838, oral sections with a non-readers intelligence test was 0.786, computation with a non-readers intelligence test 0.795 and the total with the same tests 0.826. His findings suggested that most of the variance of the mathematics test could be accounted for by a general factor it has in common with the intelligence test. To support the validity of this test Young quotes a correlation of 0.85 with the Leicester Number Test for a group of 145 children with a mean age of 6 years 11 months. This test has limitations with the group with which it has been used in the detailed studies in that the more able children reached the upper level of the mathematics ages for the test before the end of the series. However it was necessary to use a test on which the less able children had a chance to show some improvement at a very basic level and for reasons of comparison it was felt better to use one test only. At the time of the commencement of the school based research there were few tests of mathematics available so that the choice was limited. In the early part of the series of case studies there was not an equivalent test that covered the wide ability range but by 1980 the Y Mathematics series which was standardised in 1979 was available. This series was produced by Young as a continuation of his Group Mathematics Test. This series would have been a valuable one to use with the more able children had it been available earlier. Even so it was of value to use the same test throughout in order to have a direct comparison of additional concepts developed each time.

Analysis of results.

The percentages of children with correct results on each question in the oral sections for all three years of testing are shown in Tables 1 and 2.

Percentages are used as a method of comparison of different sized samples in order to pick out general trends. These general trends are shown more clearly in the form of graphs which accompany the analysis of results for each year. These are as follows:-

Fig.19.Groups with Spina Bifida and other disabilities 1976. Oral section A. Fig.20 shows Oral section B.

Fig.21.Groups with Spina Bifida and other disabilities 1978. Oral section A. Fig.22 shows Oral section B.

Fig.23.Groups with Spina Bifida in 1976 and 1978. Oral section A. Fig.24 shows Oral section B.

Fig.25.Groups with other disabilities in 1976 and 1978. Oral section A. Fig.26 shows Oral section B.

In order to ascertain whether the differences between the groups, in terms of correct answers, were statistically significant, the Chi-squared test for dichotomous variables was used(Crocker 1969). A figure of 0.05 was set as the lowest acceptable level of significance taken to indicate that the differences between

Percentage of children with correct results on the oral section of the Young Maths. Test. 1976,1977,1978. Oral side A.

Concept involved.		S.B. 1976	Others 1976	S.B. 1977	S.B. 1978	Other 1978
1.Largest		89.5	89.8	88.9	90.9	85.7
	(N)	(17)	(44)	(16)	(10)	(12)
2.Counting to 3 (how many)		100	87.7	94.4	90.9	100
		(19)	(43)	(17)	(10)	(14)
3.Count,subtract 2		73.7	93.9	72.2	81.8	64.3
		(14)	(46)	(13)	(9)	(9)
4.Series-missing number		68.4	79.6	77.8	72.7	50
		(13)	(39)	(14)	(8)	(7)
5.Divide by 2		57.9	65.3	22.2	45.5	42.8
		(11)	(32)	(4)	(5)	(6)
6.Count,another 1		73.7	77.5	77.8	72.7	57.1
		(14)	(38)	(14)	(8)	(8)
7.Shape constancy		57.9	71.4	61.1	54.5	50
		(11)	(35)	(11)	(6)	(7)
8.½,how many left		36.8	59.2	27.8	0	42.8
		(7)	(29)	(5)	(0)	(6)
9.Twice as many		26.3	46.9	27.8	27.3	21.4
		(5)	(23)	(5)	(3)	(3)
10.Spatial ability		31.6	46.9	27.8	45.5	50
		(6)	(23)	(5)	(5)	(7)
11.Place value(10 s)		36.8	55.1	38.9	18.2	28.6
		(7)	(27)	(7)	(2)	(4)
12. ¾ full		31.6	46.9	33.3	45.5	50
		(6)	(23)	(6)	(5)	(7)
13.Series,in threes		10.5	38.8	27.8	0	21.4
		(2)	(19)	(5)	(0)	(3)
14.Middle sized		15.8	22.4	16.7	27.3	14.3
		(3)	(11)	(3)	(3)	(2)
15.Figure ground		10.5	36.7	11.1	36.4	21.4
		(2)	(18)	(2)	(4)	(3)
Number of children		19	49	18	11	14

Table 1.

Percentage of children with correct results on the oral section of the Young Maths Test. 1976,1977,1978. Oral side B.

Concept involved.	S.B. 1976	Other 1976	S.B. 1977	S.B. 1978	Other 1978
1.Most (N)	84.2 (16)	89.8 (44)	83.3 (15)	100 (11)	78.6 (11)
2.Count, subtract 1	68.4 (13)	89.8 (44)	66.7 (12)	81.8 (9)	78.6 (11)
3.Fig.ground, squares, crosses.	89.5 (17)	85.7 (42)	83.3 (15)	90.1 (10)	64.3 (9)
4.Abstraction, times 2	63.1 (12)	77.5 (38)	50 (9)	63.6 (7)	50 (7)
5.½ related to x2	42.0 (8)	69.4 (34)	27.8 (5)	45.4 (5)	35.7 (5)
6.Ordination 5th	68.4 (13)	71.4 (35)	50 (9)	45.4 (5)	42.8 (6)
7.1 to 1 correspondence	52.6 (10)	73.5 (36)	38.9 (7)	54.5 (6)	42.8 (6)
8.Addition, x10	31.6 (6)	59.2 (29)	22.2 (4)	9.1 (1)	28.6 (4)
9.Telling time	36.8 (7)	57.1 (28)	27.8 (5)	27.3 (3)	14.3 (2)
10.Shape constancy	31.6 (6)	53.1 (26)	16.7 (3)	18.2 (2)	42.8 (6)
11.Fig.ground, bigger, smaller.	42.0 (8)	61.2 (30)	50 (9)	54.5 (6)	50 (7)
12.Twice as many, altogether	21.0 (4)	51.0 (25)	11.1 (2)	0 (0)	14.3 (2)
13.Counting, perspective	26.3 (5)	38.8 (19)	11.1 (2)	18.2 (2)	21.4 (3)
14.Theoretical subtraction with halves.	10.5 (2)	36.7 (18)	5.5 (1)	0 (0)	28.6 (4)
15.Odd and even numbers	5.3 (1)	18.4 (9)	11.1 (2)	9.1 (1)	7.1 (1)

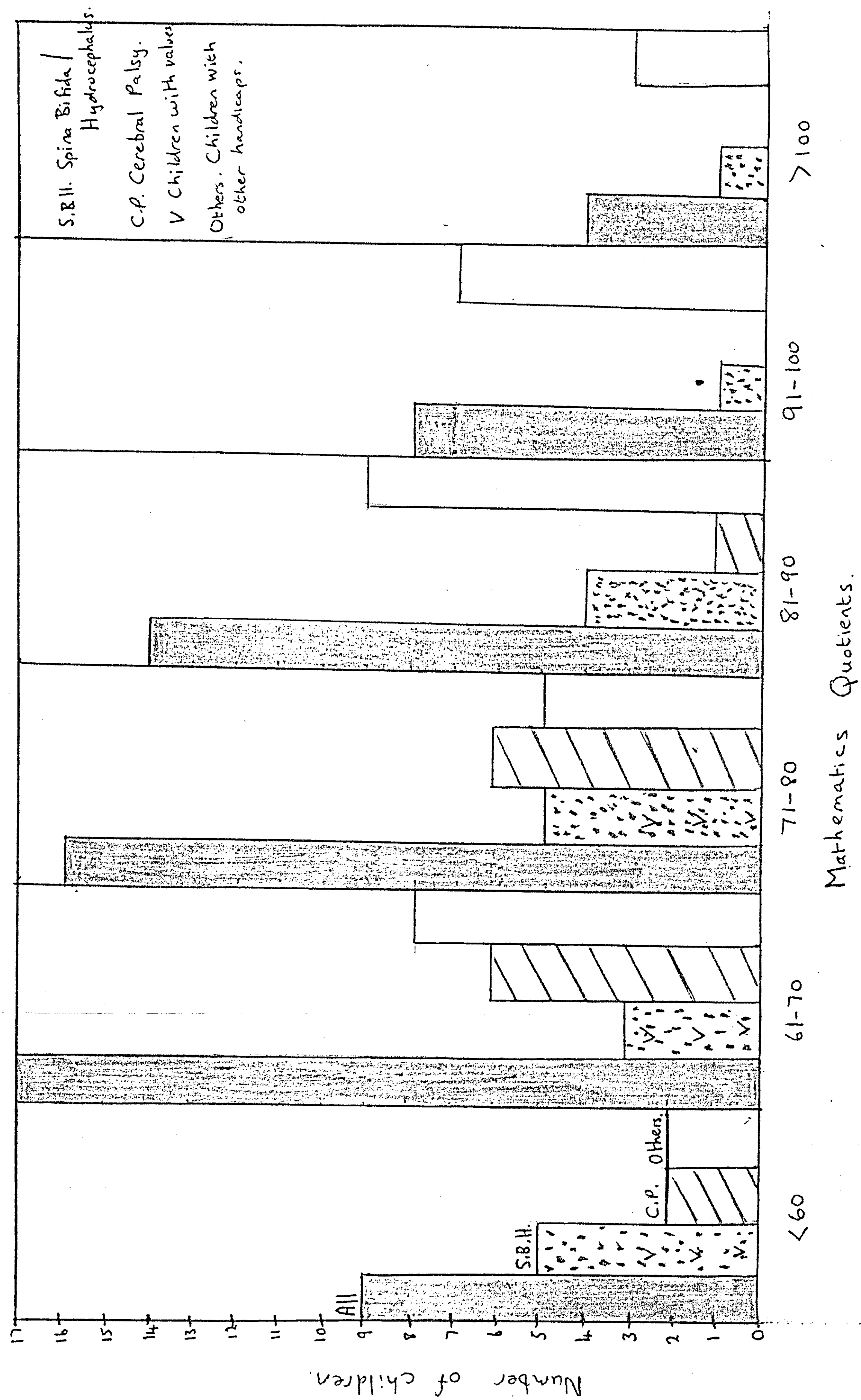
Table 2.

the groups were unlikely to be caused by chance. A Chi-squared of 3.841 was the critical level necessary for one degree of freedom(Fisher 1932, reprinted in Guilford 1965). Due to the fact that some of the cells in the two-by-two tables contained less than ten observations it was necessary to use the Yates correction for continuity in order to avoid obtaining a falsely high Chi-squared.

Mathematics Quotients showing different handicaps.

Young Mathematics Test 1976.

Figure 18.



The results obtained in 1976.

General trends. The overall results of this study are shown on the preceding page (Fig.18).
As can be clearly seen from the comparative graphs(Fig.19/20) the 19 children with Spina Bifida were consistently poorer than the 49 with other disabilities on all but two of the questions. These were two of the simplest questions. The latter group contained 15 children with cerebral palsy and 34 children with other disabilities none of which was likely to have resulted in brain damage.

The differences shown by the two groups on specific questions.

The difference between groups was only significant at the .05 level on one question but several others are worthy of comment.The following questions were from Side A of the test.

Question Two The only question on which the children with Spina Bifida performed better than the children with other disabilities was this question which involved counting to three in a straightforward manner. However the difference between the two groups was small and not statistically significant. It does show that the Spina Bifida children were capable of performing this simple counting operation which involved little thought.

Question Thirteen This was the only question on this side of the test where the difference between the two groups reached the .05 level of significance with a Chi-squared of 3.8807.
This involved filling in a missing number in a series which increased by threes. It was therefore necessary to be able to work out the sequence in order to fill in the number. Only 10.5% of the children with Spina Bifida were correct in this compared to 38.4% of the children with other disabilities. The difference was not so pronounced in Question four which was a similar question but where the series only increased in ones. The difference between the groups becomes more obvious at this more advanced level where understanding and reasoning ability is required.

Question Fifteen. The difference between the two groups on this question is quite large at 26.2% but does not reach the .05 level of significance with a Chi-squared of only 3.3553. However it does give some indication of the

A comparison of the percentage of correct answers gained on each question on the oral section (A) of the Young Maths Test by a group of children with Spina Bifida and a group with other disabilities. 1976.

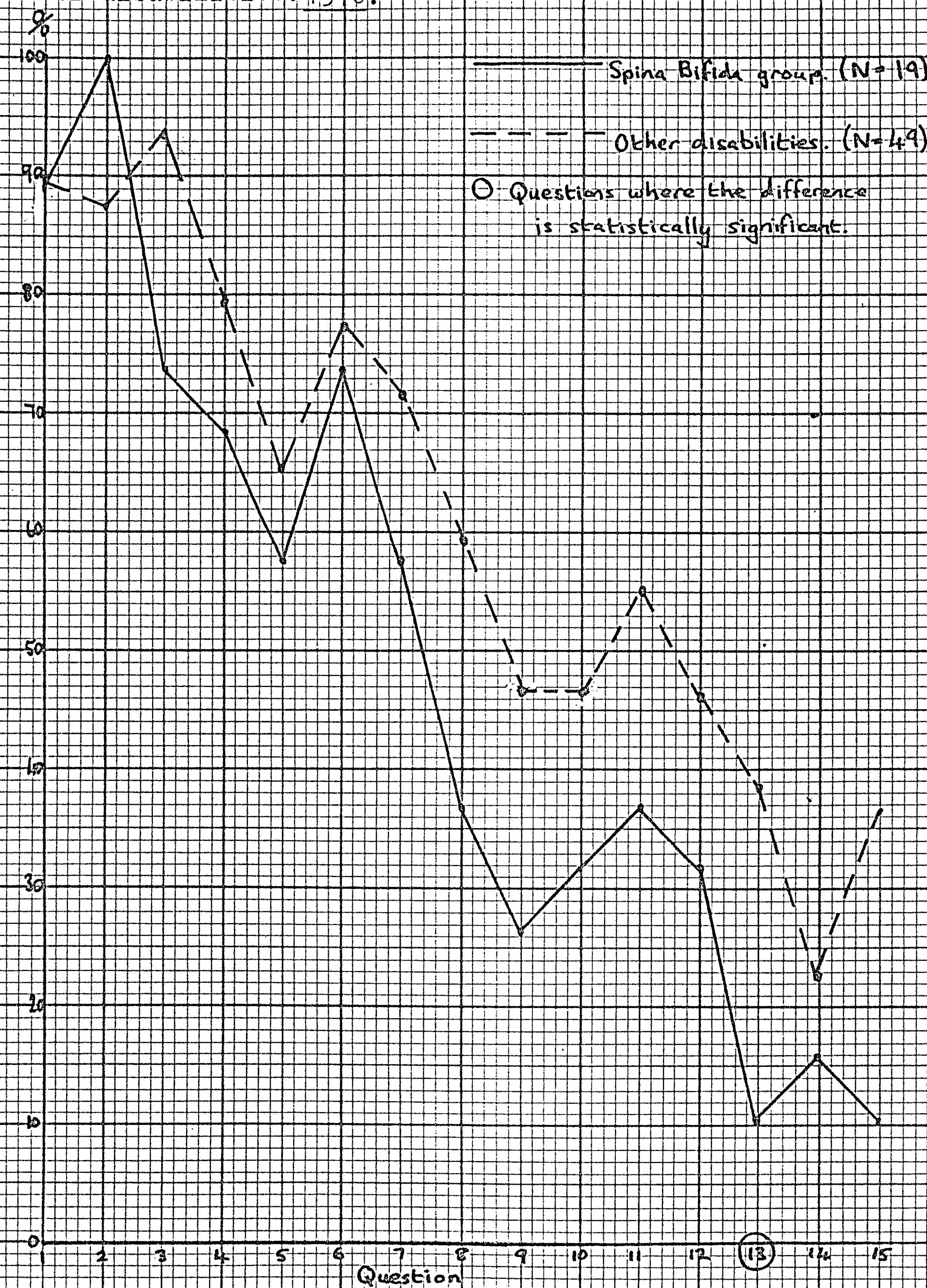


Figure 19.

A comparison of the percentage of correct answers gained on each question on the oral section (B) of the Young Maths Test by a group of children with Spina Bifida and a group with other disabilities. 1976.

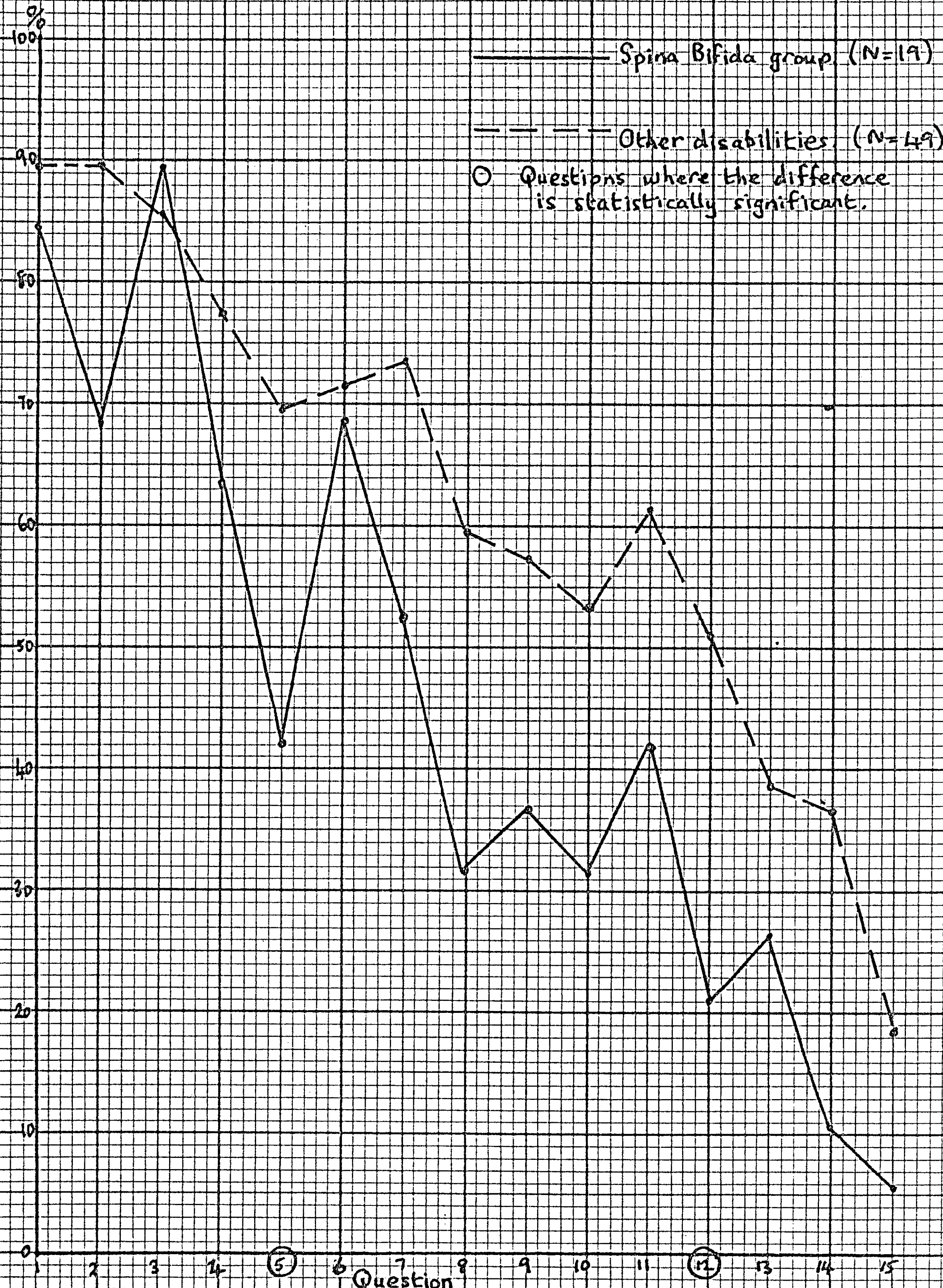


Figure 20.

possible problems shown by children with Spina Bifida on tests which involve visual perception, particularly in the area of figure-ground discrimination. This test involves selecting one of several intersecting circles.

Question Three This is another question on which the difference between the two groups just misses the .05 level of significance with Chi-squared being 3.6088. There is in fact a 20% difference between the groups. It is the first question on the test which requires any element of abstract thought and perhaps illustrates one of the main problem areas shown by the children with Spina Bifida. There were no difficult concepts involved but it was necessary to use both addition and subtraction having worked out what processes were required. In the earlier questions particularly the second one these children had shown that they could cope with simple addition as they had all answered that question correctly.

Side B.

On this side two questions show a statistically significant difference between the two groups with three more being just short of the required level.

Question Five and Question Twelve. These were the questions where the difference between the groups was significant at the .05 level with Chi-squared 4.1604 and 3.876. These questions both involve concepts related to the two-times-table and require application of the table rather than rote learning. It would appear from these results that the children with Spina Bifida were much weaker than the children with other disabilities in this area.

Question Two As on Side A this first question requiring any abstraction had a noticeably lower success rate among the children with Spina Bifida with the difference just failing to reach the .05 level of significance (Chi-squared 3.1715). Like Question Three on Side A it involved adding and then subtracting at a very simple level.

Question Eight This question also involved two operations, addition and multiplication and the difference between the groups just failed to reach the required level of significance with a Chi-squared of 3.1447.

<u>Question Fourteen</u> with a Chi-squared of 3.335 was just outside the required level but again helps to show the problems shown by children with Spina Bifida on questions involving abstraction. This question was completely theoretical with no picture to help. A knowledge of 'halves' was required and it has already been suggested in a consideration of Questions Five and Twelve that this is a problem area.

Generally it would appear that the children with Spina Bifida can cope with the very basic process of counting but begin to have problems where it is necessary to have an understanding of the concepts used and to reason out the methods required to solve problems.
Figure 18 shows that many of the children with Cerebral Palsy were also poor at maths and this will have lowered the scores of their group in this analysis somewhat. However they did form only one third of this group and performed at a higher level than the group of children with Spina Bifida.

<u>The results obtained in 1977</u>.

The results of the children tested in 1977; those recorded in Chapter Three (Gallagher 1977), but not previously analysed, fall very much into line with the results of the children with Spina Bifida from the previous year. There is some overlap with nine of the children being tested on both occasions.
Using Chi-squared no significant differences were found between the two groups although Question Five on Side A came close with a Chi-squared of 3.5119. This is a question which involves dividing by two and the difference may well reflect the slightly younger age group of those studied in 1977. This group was drawn from the Junior part of the school only, whereas some Seniors had been involved in 1976.
In 1976 it was found that the children with Spina Bifida had significantly poorer results than the children with other disabilities on two of the more abstract questions relating to the two-times-table.
The results of the children studied in 1977 were also

compared to those of the children with Spina Bifida studied in 1978, using Chi-squared. No significant differences were found between the groups although on a considerable number of the questions the 1978 group had a greater percentage of correct answers. This is of interest as the 1978 group was drawn only from the bottom two Junior classes in the school whereas the 1977 group was from all four Junior classes. This meant that a number of the children in the 1977 group were two years older.

The results obtained in 1978.

General trends. The 1978 group included 25 children aged seven to nine years. This included 11 children with Spina Bifida and 14 with other disabilities. Only two of the children with Spina Bifida had been tested in 1977 as the new bottom Junior class contained nine such children all of whom are studied in detail in case studies later. This was the biggest group of children with Spina Bifida to go through the school in one class, and they differed from their predecessors in that they had all been educated from nursery level. As a group they appeared far more lively than is often expected of these children and compared very favourably with the rest of the class in this respect. Of the other 14 children in the class only four had conditions which were not associated with brain damage. The group as a whole included only the younger age range in whom mathematical concepts would be expected to be less developed. The results are interesting in that on some questions the children with Spina Bifida fared better than the children with other disabilities and overall there are few questions where there is a large discrepancy between the groups. The comparative graphs(Figs.21/22) show this lack of difference between the groups clearly.

Specific questions.

Question Eight on Side A is the only one in which the difference between the two groups is significant with a Chi-squared of 4.0759. In this question none of the children with Spina Bifida were correct compared with 42.8% of the children with other disabilities. This question involved the concepts of 'half' and 'how

A comparison of the percentage of correct answers gained on each question on the oral section (A) of the Young Maths Test by a group of children with Spina Bifida and a group with other disabilities. 1978.

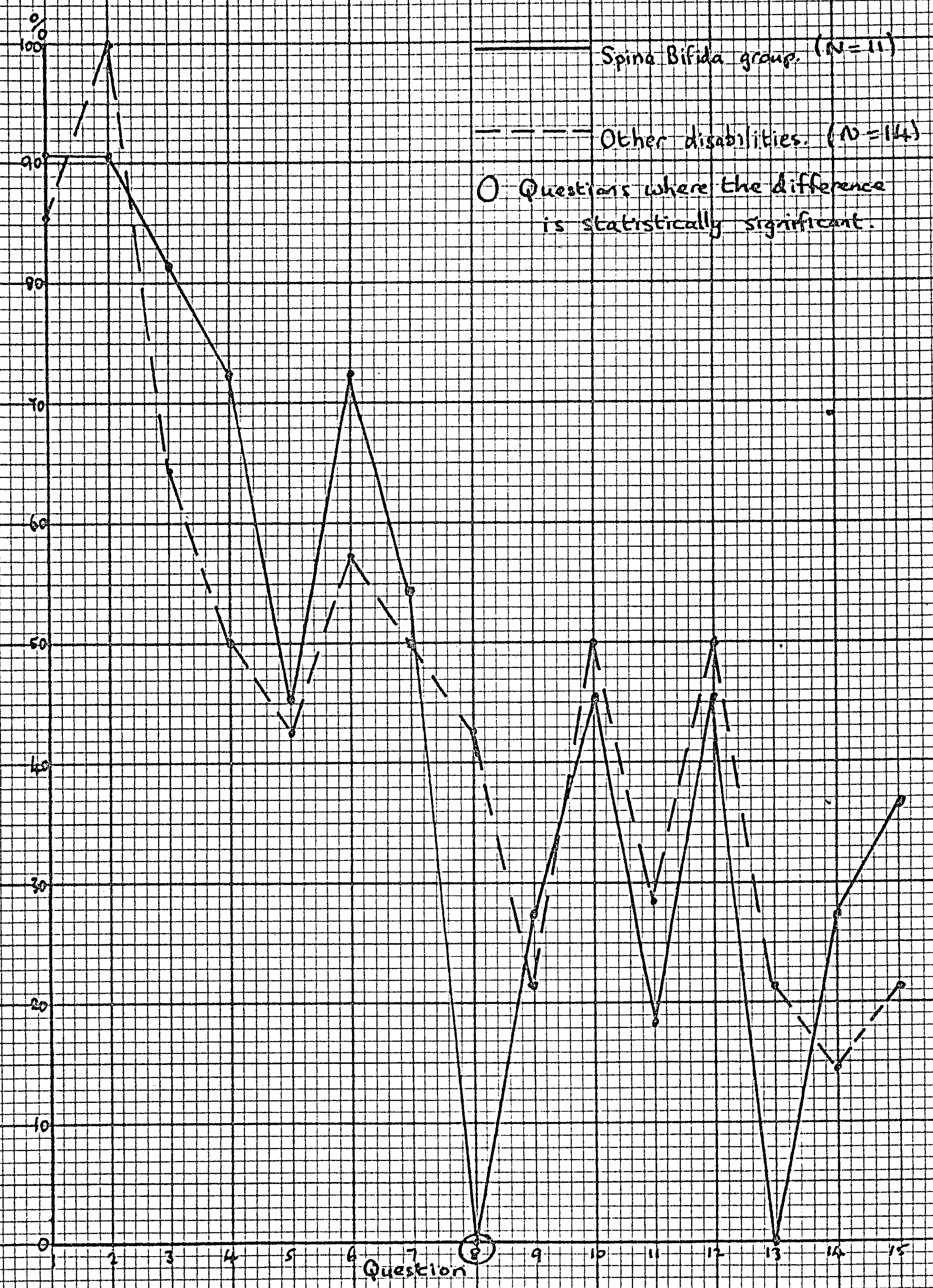


Figure 21.

A comparison of the percentage of correct answers gained on each question on the oral section (B) of the Young Maths Test by a group of children with Spina Bifida and a group with other disabilities. 1978.

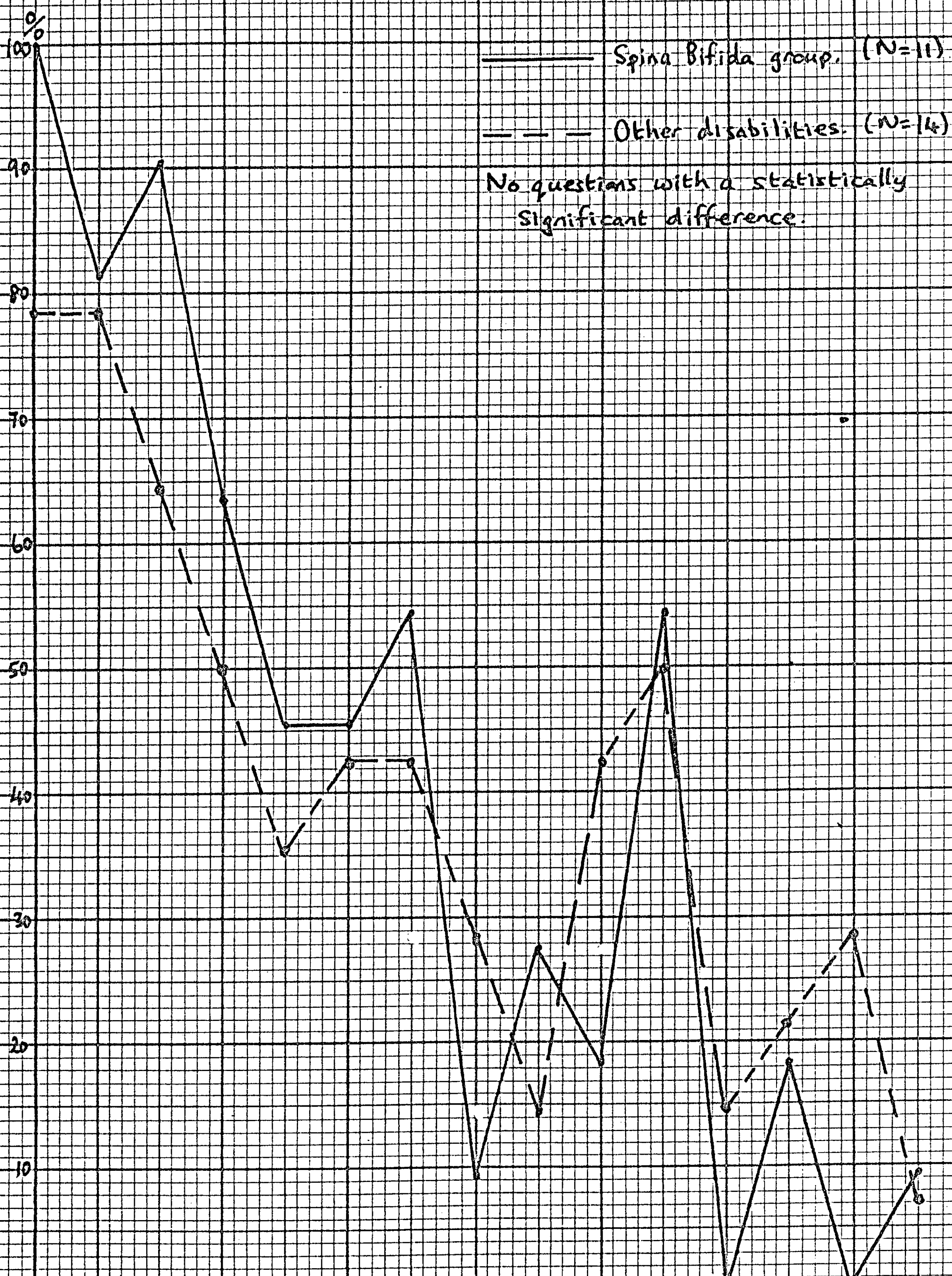


Figure 22.

many left' and required the child to understand that to find half of a number necessitated dividing by two.On Question Five which also involved dividing by two but where the process involved was more obvious the children with Spina Bifida performed slightly better than the others. Other questions which resulted in complete failure by the children with Spina Bifida were two of those on Side B which related to application of the two-times-table (Seven and Fourteen). In 1976 questions relating to this area presented problems for the children with Spina Bifida.

A comparison of the results obtained in 1976 and 1978.

Having found a much greater difference in performance on the Young Maths Test between the group of children with Spina Bifida and those with other disabilities in 1976, than between similar groups in 1978 a comparison of each group on the two occasions was carried out.

The children with Spina Bifida.

As can be seen from the comparative graphs(Figs.23/24) the two Spina Bifida groups were very similar in their success rates on the various questions in the test. Only one question came anywhere near to showing a significant difference and that was Question eight on Side A with a Chi-squared of 3.4271. This is the only question where a significant difference was found between the group of children with Spina Bifida and those with other disabilities in 1978. In 1978 the Spina Bifida group failed totally on that question.

As the group tested in 1976 ranged in age from seven to twelve years and that in 1978 only from seven to nine the results in 1976 could be expected to be significantly better in 1976 as these children had had three extra years in which to develop their mathematical concepts. That this is not the case would suggest that the children tested in 1978 were comparatively more advanced than those tested in 1976. As has already been stated the results were very similar.It could also be a reflection of the small number in the study.

The children with other disabilities.

Having found that the two groups of children with Spina

A comparison of the percentage of correct answers gained on each question on the oral section (A) of the Young Maths Test by 2 groups of children with Spina Bifida, one studied in 1976 and the other in 1978.

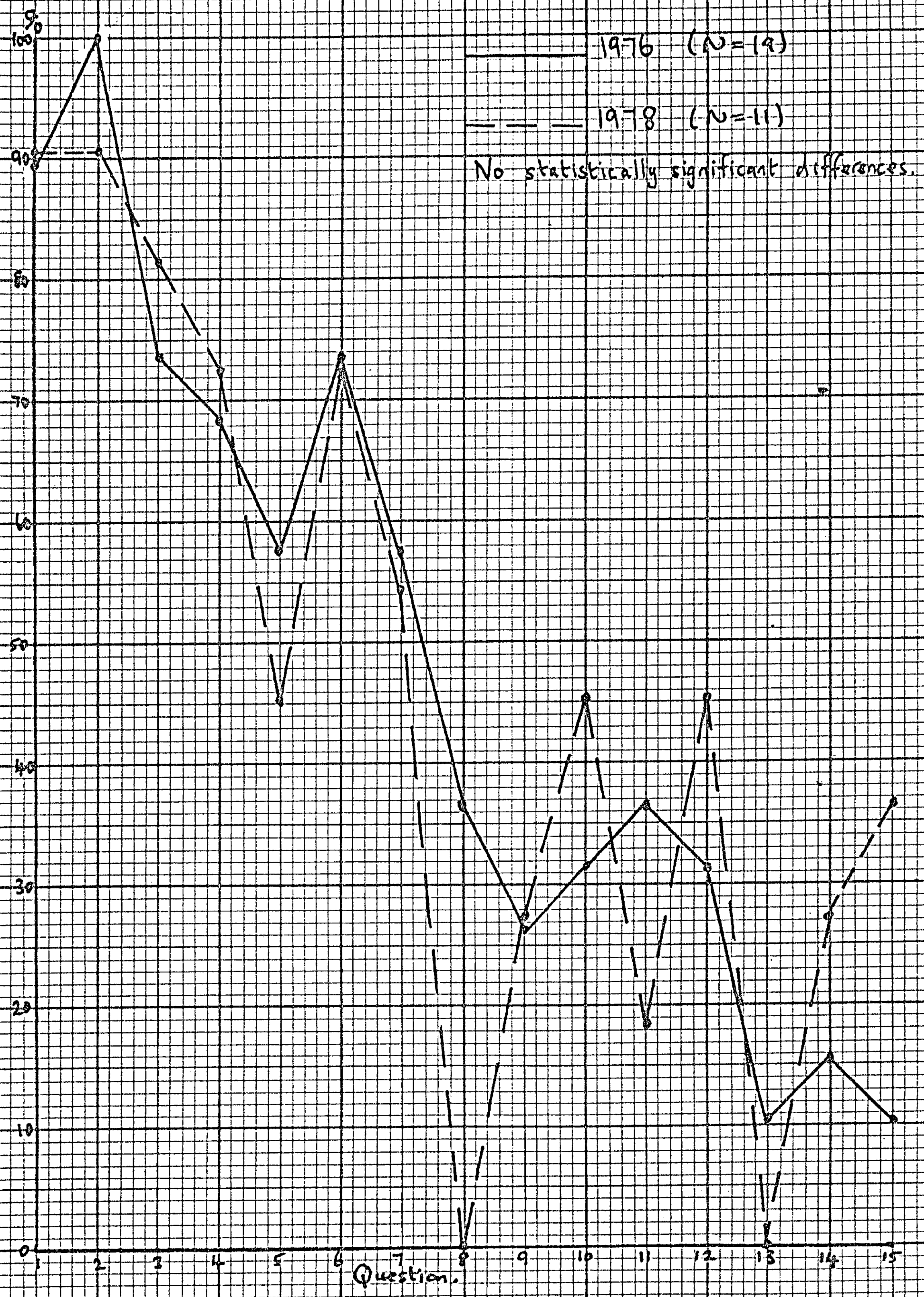


Figure 23.

A comparison of the percentage of correct answers gained on each question on the oral section (B) of the Young Maths Test by 2 groups of children with Spina Bifida, one studied in 1976 and the other in 1978.

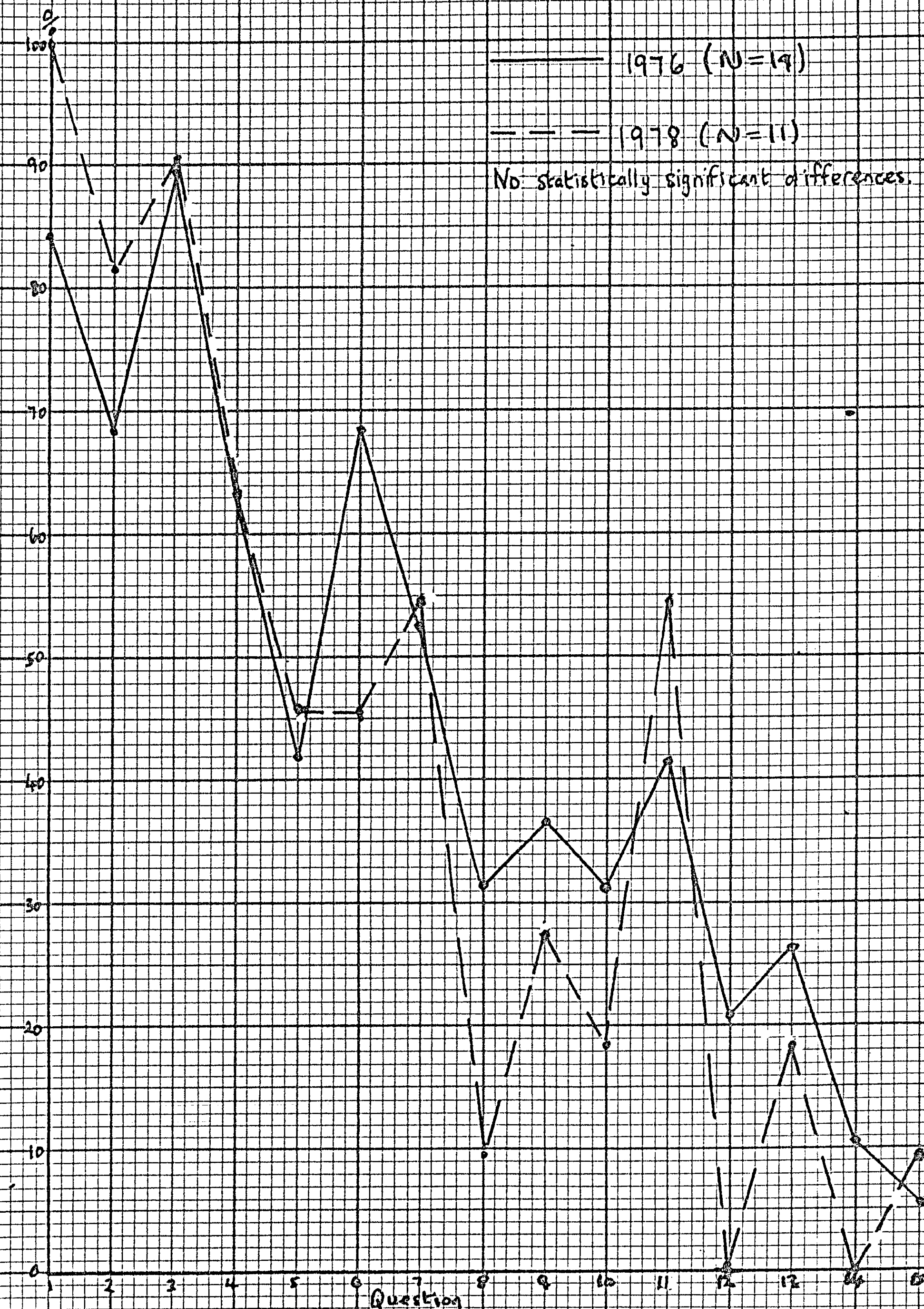


Figure 24.

Bifida performed at similar levels on the Young Maths Test it might be expected that the two groups of children with other disabilities would do likewise.However this was not the case with the children with other disabilities in 1976 performing at a much higher level than those tested in 1978 (Figs.25/26). The age difference has already been mentioned but the other factor of importance is likely to be the incidence of brain damage within the groups. In the 1976 group only 15 out of 49 children had some element of brain damage whereas in 1978 10 out of 14 children had conditions associated with brain damage which was a far higher proportion.

Questions showing significant differences.

Side A- Question 3. This has a Chi-squared of 6.1389 which is significant at the .02 level. This was the first question which required any abstraction and was one which was mentioned in this light in a comparison of the children with and without Spina Bifida in 1976. The children with other disabilities tested in 1978 appear to have the same problem of being unable to move on from simple mechanical addition to apply a further process of very simple subtraction. In Question two this group of children had shown that they could cope with simple addition.

Side B- Questions Five and Twelve. Both of these questions show a significant difference between the 1976 and 1978 groups of children with other disabilities (Chi-squared of 3.9050 and 4.5937). Again these questions were ones where a significant difference was shown between the children with Spina Bifida and those with other disabilities in 1976. As already mentioned the children without Spina Bifida tested in 1978 are performing in a very similar way to those with this condition.

Side B- Question Nine. This is the only occasion on which this question presents as a significant difference between groups (Chi-squared 6.3920 which is significant at .02 level). This question involves telling the time from a picture of a clock and it seems very likely that the difference on this question occurs because of the fact that the group tested in 1978 is considerably younger.

A comparison of the percentage of correct answers gained on each question on the oral section (A) of the Young Maths Test by 2 groups of children with other disabilities, one studied in 1976 and the other in 1978.

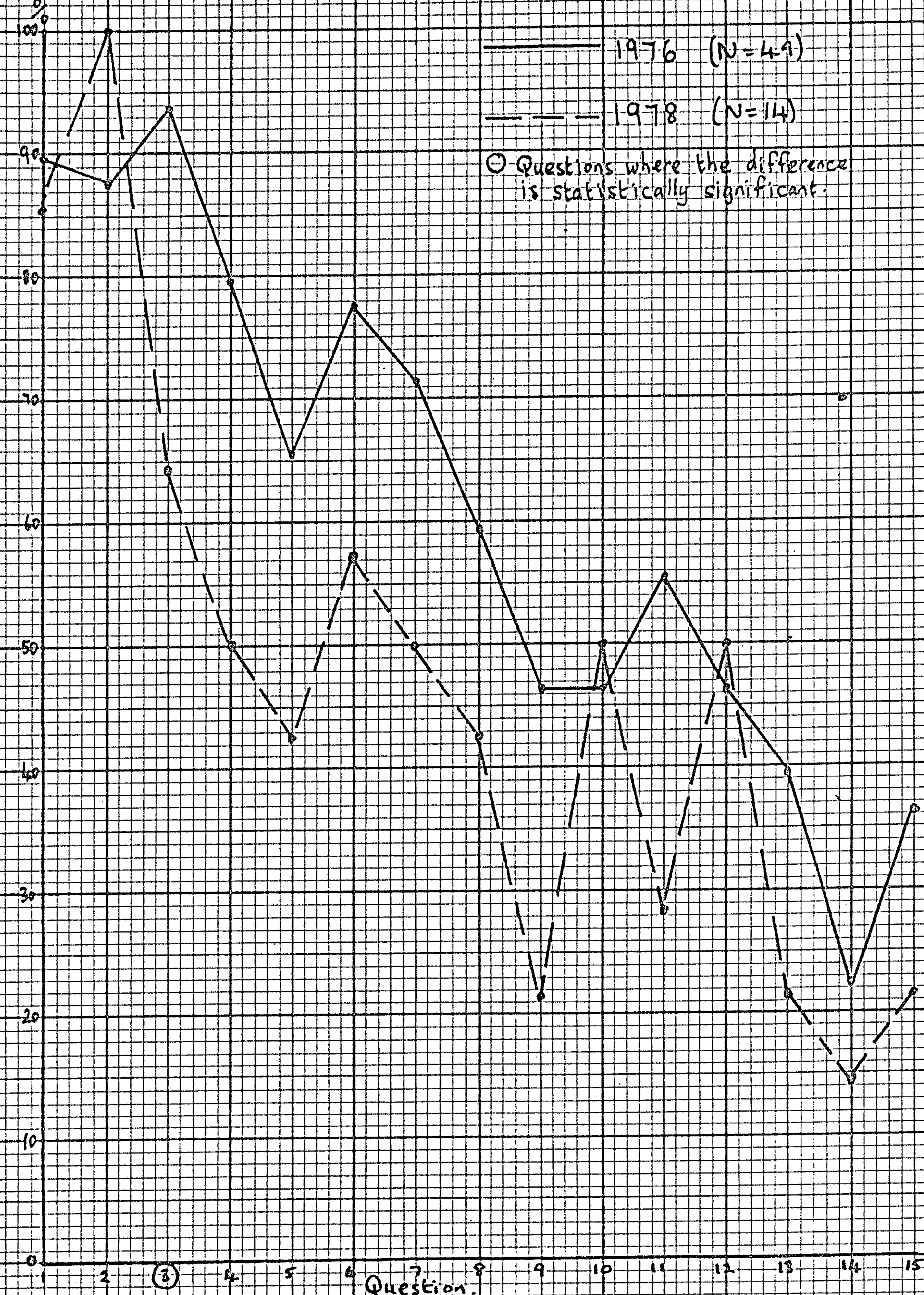


Figure 25.

A comparison of the percentage of correct answers gained on each question on the oral section (B) of the Young Maths Test by 2 groups of children with other disabilities, one studied in 1976 and the other in 1978.

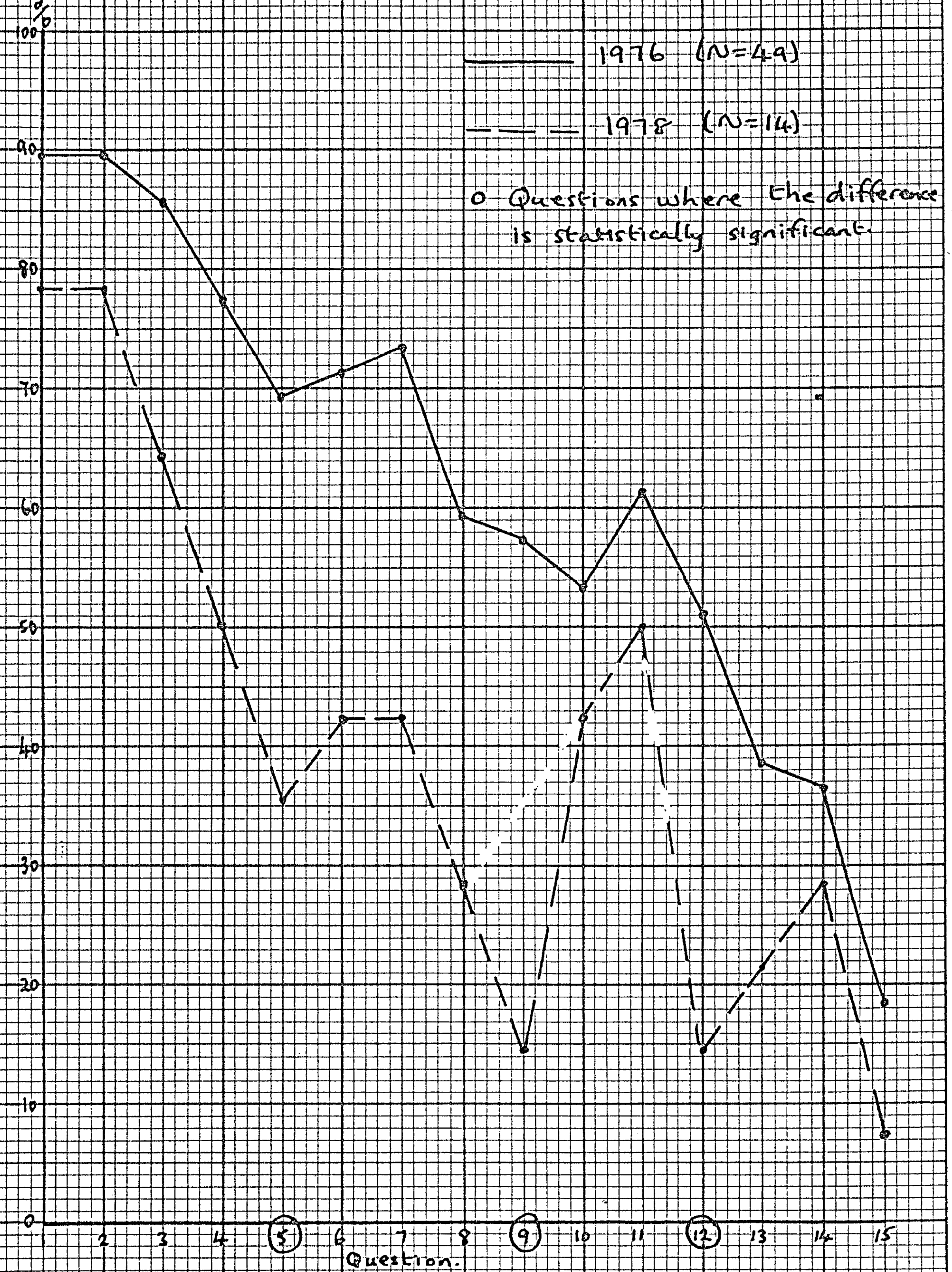


Figure 26.

The children with Spina Bifida who were tested in 1978 also performed poorly on this question. This possibly suggests that the children had not yet been taught how to tell the time.

Discussion of the results obtained on the Young Group Mathematics Test in all three years.

On the test results generally all the groups were more successful at concrete examples where only simple counting was involved. These findings were similar to those of Gibson(1981). Concepts like 'largest' and 'most' got good responses but even when slight abstraction was involved the success rate went down. The group of children with disabilities other than Spina Bifida, who were tested in 1976 were the least affected by this. On the computation sections of the test all the groups performed poorly with the differences between the groups being small. This may relate to the fact that the children do not normally complete sums written across the page which would require an understanding of place value. Children with spatial problems may well have more difficulty with this style of presentation than they would with the figures in columns. The mean results are shown here to indicate general trends only, the maximum score being 15.

	S.B. 1976	Others 1976	S.B. 1977	S.B. 1978	Others 1978
Addition	5.4	8.4	4.4	3	4.7
Subtraction	5.3	7.8	4.4	3	4.2
N	19	49	18	11	14

The oral sections of the test do not require purely knowledge and understanding of concepts related to mathematics but also the ability to work out what sort of calculation is required, which involves a certain degree of logical thought. As Gellman and Gallistel(1978) suggest it is necessary to look at children's ability in arithmetic in terms of their ability to count and their ability to reason arithmetically, the former being possible purely as a result of rote learning.

The main findings that can be drawn out of the consideration of the results in this section are as follows:-

a) In 1976 the group of children with Spina Bifida were generally poorer than the group of children with other disabilities, on the Young Group Mathematics Test. This covered the age range seven to twelve years. The majority of the children with other disabilities did not suffer from any known neurological damage.

b) In 1978 there was little difference between the children with and those without Spina Bifida in terms of performance on the Young Mathematics Test. The majority of children without Spina Bifida had some form of neurological damage.

c) In a comparison of the results obtained by children with Spina Bifida in 1976 and 1978 little difference was found. This was surprising as the 1976 group ranged in age from seven to twelve years whilst the 1978 group were only from seven to nine years. Thus the results of the group tested in 1976 would be expected to be better due to the fact that some of them had had up to three extra years of schooling and experience in which to develop mathematical concepts. This would suggest that the children with Spina Bifida tested in 1978 were at a more advanced level, in terms of the development of mathematical concepts, than those tested in 1976. It is possible that those children tested in 1976 had reached a plateaux in their mathematical development which would also be reached by the younger children. The lack of a statistically significant difference between the groups could also reflect the small numbers involved.

d) In a comparison of the results obtained by the children with other disabilities in 1976 and 1978 the findings did not parallel those of the children with Spina Bifida. The group of children tested in 1978 performed at a lower level than those tested in 1976. The difference could have been caused by the lower ages of the children or the fact that the group of children tested in 1978 contained a greater proportion of children with neurological damage.

There is little doubt from the results considered that many children with Spina Bifida have difficulty in developing mathematical concepts and it would appear that other children who have some form of neurological damage are likely to have similar problems. Of all the groups studied the 1976 group of children with disabilities which did not involve neurological damage performed best on the Young Group Mathematics Test.

It is necessary to interpret the results given here with caution due to the small number of children involved but they would seem to lend support to the idea that children with neurological damage, which includes those with Spina Bifida and Hydrocephalus, are likely to have problems in developing mathematical concepts.The reasons as to why this is the case will be discussed later.

CHAPTER SIX. RESEARCH FINDINGS.

Part 2. Case Studies.

Case Studies.

The choice of tests for this part of the research.

It is convenient within any research to use standardised tests because they provide norms against which the performance of the child can be judged. Many such tests are falling into disrepute and the recently published 'Tests in Education'(Levey and Goldstein 1984) which contains reviews of many tests which are in regular use in Britain emphasises this point. The Editors summarise some of the main findings as follows:-

> It is clear that there is much to be improved in the world of British test publishing. Apart from test content itself perhaps the most serious weakness is the lack of good supporting material. It has struck us forcibly that the most important gaps in information are to do with the aims and purposes of the tests and the technical side of sampling and standardisation.

These are very serious critisisms to which they add the comments that few of the tests provide adequate, up to date norms and that many of them seem to lack rationale and purpose.

Seen in this context, although the tests used in this study can be seriously critisised in some of these respects many of the possible alternatives show the same problems. For instance Stibbs, in Levey and Goldstein(1984) describes the Schonell Graded Word Reading Test as 'dated and generally deficient'. This is a test which has been used in a number of pieces of research and in fact was used in the Sheffield large scale data which will be considered in the next chapter.

The alternative to using British tests is to use American ones where the problem arises of them having been standardised on American populations and only rarely having British norms.

The idea for this work arose from an essentially practical problem whilst teaching in a school for physically handicapped children of which about one third had Spina Bifida and Hydrocephalus, the problem being their difficulty in developing mathematical concepts.

The tests used in this study were chosen because they were already in use in the school concerned although it was realised that they may have limitations. This enabled testing, using such measures as the Young Group Mathematics Test and the Daniels and Diack Reading Test to be carried out regularly to keep staff informed of pupils' progress in these areas, instead of taking up valuable time by using tests which did not fit in with the records already in existence. It was usual for reading to be tested annually although this was not necessarily the case with mathematics. The Young Group Mathematics test has been fully described in the previous section and details of the other tests can be found in Appendix 1.

To get a general idea of the intellectual level of the children the Raven's Coloured Progressive Matrices and Crichton Vocabulary Scale were used as they give crude levels for performance and verbal abilities respectively. Fulthorpe(1974) worked out rough IQs for children with Spina Bifida based on the scores on Raven's Matrices and found that his results were very similar to those of other researchers who had used the WISC. The assessment of performance skills was backed up by using the Frostig Developmental Test of Visual Perception and the Bender-Gestalt Test and the verbal side by using the English Picture Vocabulary Test.

Tew(1976) concluded that the Frostig Test is largely one of general intelligence and he found that in Spina Bifida children of 5½ years of age it correlated highly with scores on the WISC. Most previous research has been carried out using the Weschler Intelligence Scale for Children(WISC) as the measure of intelligence and this contains both verbal and performance scales. However this is generally only available for use by psychologists and although it gives a somewhat wider profile of skills than the tests used here it is also more time consuming. It was felt that it was better to adhere to the principles of taking up as little teaching time as possible.

By the 1984 follow up testing, the Young Group Mathematics Test was not the ideal test to use as the upper age limit for its recommended use had been well exceeded. The upper age limit of eleven years was also exceeded by 1984 on the Bender-Gestalt Test, Crichton Vocabulary Scale and Raven's Coloured Progressive Matrices.

Testing was carried out on nine children with Spina Bifida and Hydrocephalus, all of whom were shunt treated and were in the same class at school. The major part of the testing was carried out during their first two years in the Junior department of a school for physically handicapped children. Follow up testing was carried out in mathematics a year later and in several areas after a gap of three years. Testing was carried out as follows:-

<u>October 1978.</u>

Young Group Mathematics Test.
Daniels and Diack Standard Reading Test or Holborn Reading Scale.
Visual perception sections of Daniels and Diack Reading Test.
Frostig Developmental Test of Visual Perception.
Raven's Coloured Progressive Matrices.
Crichton Vocabulary Scale.
Bender-Gestalt Test(Koppitz).
English Picture Vocabulary Test.
Draw-a-Man Test.
Piagetian tests of conservation of mass and number.

<u>October 1979.</u>

Young Group Mathematics Test.
Daniels and Diack Standard Reading Test or Holborn Reading Scale.
Frostig Developmental Test of Visual Perception.
Raven's Coloured Progressive Matrices.
Crichton Vocabulary Scale.
Piagetian tests of conservation where needed.

<u>July 1980</u>.

Young Group Mathematics Test.
Daniels and Diack Standard Reading Test or Holborn Reading Scale.
Frostig Developmental Test of Visual Perception.
Raven's Coloured Progressive Matrices.
Crichton Vocabulary Scale.

Bender-Gestalt Test(Koppitz).

Piagetian tests of conservation where needed.

July 1981.

Young Group Mathematics Test.

Piagetian tests of conservation where needed.

June 1984.

Young Group Mathematics Test.

Holborn Reading Scale.

Raven's Coloured Progressive Matrices.

Crichton Vocabulary Scale.

Bender-Gestalt Test(Koppitz).

Piagetian tests of conservation where needed.

The full results of the tests can be found in Appendix 2, and samples of the Draw-a-Man Test can be found in Appendix 3.

The Mathematics results considered as a group.

The results obtained by the nine children on the Young Group Mathematics Test are shown in Table 3 along with the results of simple Piagetian conservation tests. Two simple tests of conservation were used with one involving the conservation of number and the other the conservation of mass. In the first one, two rows of counters were used, and having obtained agreement from the child that they were in fact equal in number, one row was rearranged. It was then noted whether the child stated that they were still equal. The second test was carried out using two balls of plasticine which were identical to start with. As has been mentioned in Chapter 4 Piagetian tests have been critisised by people such as Byrant(1984) and Donaldson(1982). However it was felt that as they were so quick and easy to administer that they were of value in giving some idea of the level of conservation achieved by the child so that this could be related to their scores in mathematics.

When looking at the results of this small group of nine children it is useful to consider whether or not they showed conservation of number or mass, particularly number, bearing in mind the comments made in earlier chapters about the development of mathematical concepts and the role of conservation in this. As has already been mentioned Piaget suggests that conservation of number is necessary before formal number work can be mastered and that this occurs about six months before conservation of mass, although the latter does not necessarily derive from the former. He would expect conservation to occur between the ages of six and nine years.

In these children where conservation of number and mass were not both evident the conservation of number appeared first in three out of four cases.

Parfitt(1979) found that children with Spina Bifida who showed delayed development on Piagetian tests also performed less well on standardised tests of mathematics carried out three years later. However he did suggest that these children went through the normal stages of number concept development but at a later age.

Table 3

Mathematics ages and Quotients obtained by the children in the case studies.

Child.		1978	1979	1980	1981	1984
	C.A.	8y1m	9y	9y8m	10y8m	13y8m
A(m)	M.A.	6.3y	7.2y	7.5y	8.4y	9.2y
	M.Q.	79	80	77 (Cn/m)	80	79
	C.A.	7y9m	8y9m	9y4m	10y4m	13y4m
B(m)	M.A.	7.3y	8.1y	9y	9.1y	Above
	M.Q.	94 (Cn/m)	91	97	91	scale
	C.A.	7y4m	8y3m	8y10m	9y10m	12y10m
C(m)	M.A.	8.4y	9.3y	10.1y+	9.9y+	Above
	M.Q.	120 (Cn)	115	114+ (Cm)	100+	scale
	C.A.	7y9m	8y9m	9y5m	10y5m	13y4m
D(f)	M.A.	6.3y	7.1y	7.2y	7.9y	8.2y
	M.Q.	82	82	77	78 (Cm)	71 (Cn)
	C.A.	7y8m	8y8m	9y4m	10y4m	13y3m
E(f)	M.A.	6.5y	6.9y	7.2y	7.9y	8.3y
	M.Q.	85	80	77 (Cn)	79 (Cm)	72
	C.A.	7y8m	8y8m	9y3m	10y3m	13y3m
F(f)	M.A.	6.4y	6.7y	7.1y	7.2y	9.2y
	M.Q.	84	78	77 (Cn)	71 (Cm)	79

The year in which the child was found to be successful on conservation tasks is shown. Cn - Conservation of number, Cm - Conservation of mass.

Table 3(cont.)

Mathematics ages and Quotients obtained by the children in the case studies.

Child.		1978	1979	1980	1981	1984
	C.A.	7y6m	8y6m	9y1m	10y1m	13y1m
G(f)	M.A.	8.2y	9y	9.3y	9.9y+	Above scale
	M.Q.	111 (Cn/m)	106	101	100+	
	C.A.	7y7m	8y8m	9y1m	10y1m	13y3m
H(m)	M.A.	-5.5y	5.8y	5.5y	5.9y	6.9y
	M.Q.	-68	68	56	-60	61
	No conservation and no real progress in maths.					
	C.A.	8y	9y	Died		
I(f)	M.A.	5.9y	5.9y			
	M.Q.	75	66			
	No conservation and no progress in maths. This child had shunt problems during this period which required operations and resulted in her death.					

Key.

C.A. Chronological Age.

M.A. Maths. Age.

M.Q. Maths. Quotient.

(m) Male. (Cn) Conservation of number.

(f) Female. (Cm) Conservation of mass.

The letters used to indicate the children are those used throughout the case studies.

N.B. Above a Maths age of 8.5 years the test is not sufficiently sensitive to be a good guide to progress. (Young 1970).Child C and Child G score right at the top of the scale. Child B does appear to reach a plateau in 1980 and then start to drop back relative to his age.

From the results shown in Table 3 it can be seen that the children can be considered in three groups based on their ability in mathematics.

Children B, C, and G,-Quotients above 90.

At the start of the study in 1978 these were the only children to show conservation of number.It might therefore be expected that their mathematical skills would be further advanced than those of the other children at this stage. This was in fact the case. The children C and G had quotients well above 100 on all occasions of testing and B's were in the 90s.

They maintained their superiority in mathematics throughout the period of the study and by 1984 they were the only children to score at the top of the scale on the Young Group Mathematics Test, despite the fact that it has a maximum maths age of only 9.9 years. When considering the scores from this maths test it must be remembered that the manual cautions that above a maths age of 8.5 years the content of the test is too limited for unqualified acceptance of the highest quotients. Thus the fluctuations in the scores of these children do not necessarily indicate fluctuations in overall performance. These more able children showed a good grasp of basic mathematical concepts and were not giving any cause for concern in maths lessons.

Children A, D, E and F, - Quotients between 70-85.

This group of children did not show conservation of number until after the age of nine years.

By 1980 Child A showed conservation of both number and mass, so it might have been expected that his mathematics results would show some improvement, because from this point he seemed to have some basic understanding upon which to build. Throughout the whole period he had a maths quotient of around 80 and maintained steady progress in the development of concepts. However by 1984 he still made seven errors on this test although his quotient remained constant. This child was the only one in the group to have better results in mathematics than in reading in the early stages of the study. However by 1984 his reading age had improved to 13 years 6 months at a chronological age of 13 years 8 months.

By 1980 children E and F had shown conservation of number but did not conserve mass until 1981. The latter is very much a spatial relationship problem and provides a basis for much mathematical thinking, whereas the conservation of number provides the basis for the early numerical work done in mathematics. Both of these children had made very slow progress in this area which is not surprising when it is considered that they were over ten years old before conservation fully occurred. By 1984 Child F had raised her maths age to 9.2 years with 7 errors on the test whereas Child E had reached only 8.3 years with 14 errors. Child D showed a similar lack of progress but did not show conservation of number until well after the age of 10 years.

Children H and I, - Quotients of less than 70.

These children showed no conservation at all during the study and Child I died of shunt complications in 1980. In the first test this child had a quotient of more than 70 but was included in this group because over the two years of testing she had made no progress in terms of maths age which remained at 5.9 years. Both these children appeared to be of very limited intelligence and had low scores in all areas, whereas some of the other children, particularly those in the previous group, presented a rather less even profile of skills.

A comparison of Reading and Maths quotients obtained by the children in the case studies in 1979.

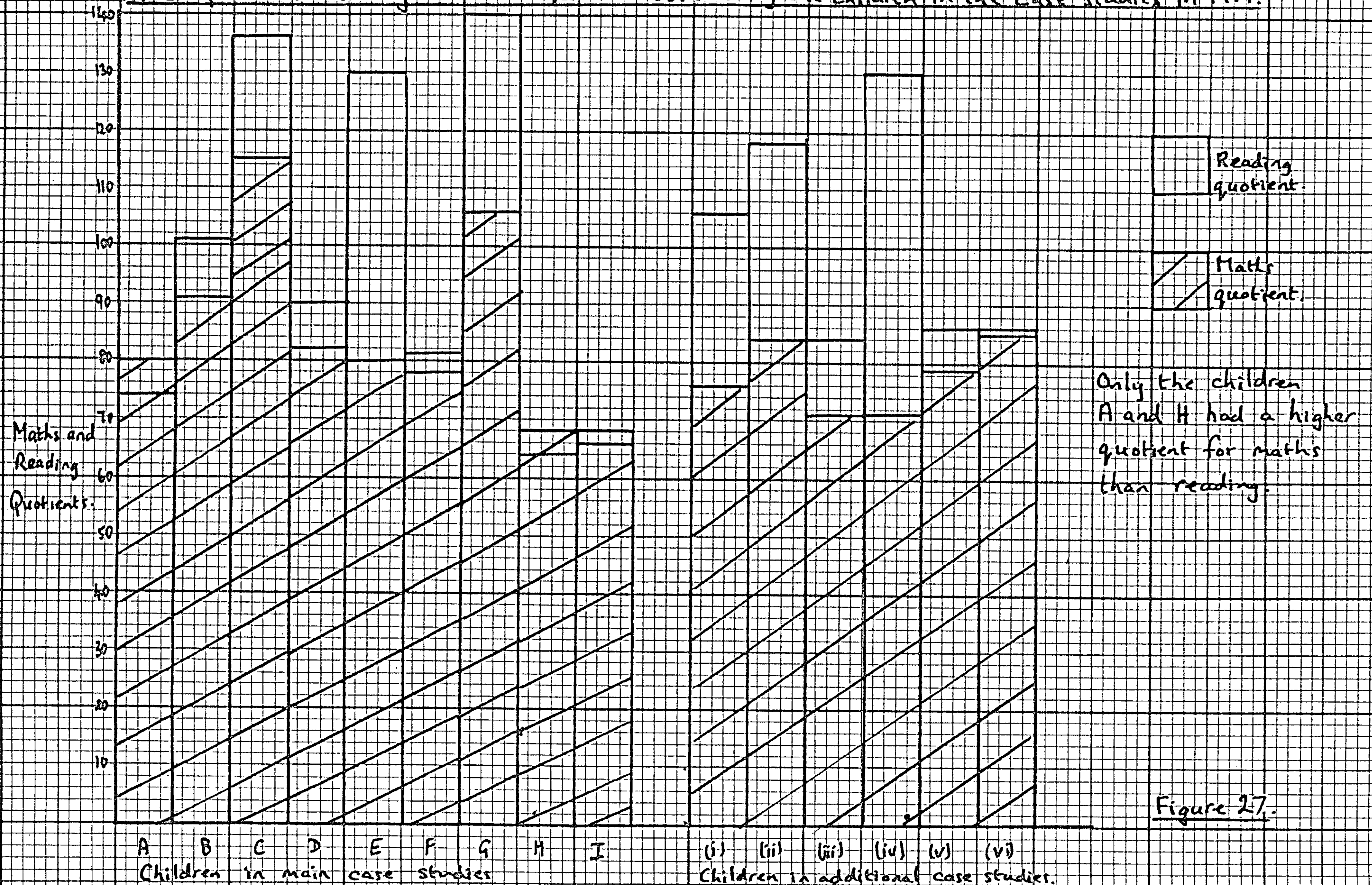


Figure 27.

Reading and Mathematics results.

(1979 comparison shown in Figure 27)

Children H and I who appeared to be of very low general intelligence achieved very poor results in both reading and mathematics. Of the other seven children five were definately more successful at reading than at mathematics. It is likely that the good early verbal skills shown by these children assisted them in learning to read. In Piagetian terms, reading could be adequately coped with at an earlier stage of intellectual development than could the development of number concepts. For the latter a certain degree of flexibility of thought is required to grasp such ideas as conservation. Prior to that stage rote learning of number skills is possible. This may account for the fact that the children can appear to be making progress when young, and score better on maths tests at this early age than they do later on, when an understanding of the concepts involved is needed to maintain a similar level. The infant school staff appear to have been misled by the early verbal ability and pseudo-counting(Skemp 1971) of these children into thinking that they were ready for formal maths long before most of them really were. It is interesting to note that three of these children were reported as knowing several of their tables before leaving the infants department. These were the children who performed well at mathematics throughout this study but it is interesting that Child G despite 'knowing' tables to five times had little understanding of them. On the first two tests she failed on the questions involving twice as many and dividing by two. This suggests that she could not make use of her rote learning of the tables at all.

The desire of teachers and parents to have children working on written sums is something that is likely to adversely affect the development of mathematical concepts, especially in these children.

By 1984 when the children were aged between 13 and 13½ years six of them were performing at or above their chronological age in reading with one child only one year and another four years retarded. Parfitt(1979) had found an improvement in reading ability at around the age of thirteen years, in children with Spina Bifida . However in mathematics only three children had reached the top of the scale which was only 9.9 years thus showing that a considerable deficit still existed in this area. Although this is only a small group of children the results do support the view that children with Spina Bifida and Hydrocephalus are more likely to have problems in developing mathematical concepts than in learning to read.

The relationship of the other results in the test battery to the ability shown in mathematics.

The results of the battery of tests were considered in relation to the child's ability as shown on the Young Group Mathematics Test. Due to the small number of children involved correlational analysis was not considered appropriate.

General information on the group of nine children.

This group had all begun their education early at nursery level and were in the same school year group. They were all Myelomeningoceles with shunt treated Hydrocephalus. By 1984 three of them had been transferred to mainstream school at the age of thirteen years. These were the children A, B and G.

Table 4. Shunting and mobility in the case study children.

a) Shunting.

Child	Situation regarding shunt.
A	Problem free.
B*	Removed at age 9years 3 months.
C*	Problem free.
D	Blockage, revisions at 1 and 2 years.
E	Removed in first year
F	Blockage, revised at 1 year.
G*	Problem free.
H	Revised at 8 months, reason unknown.
I	Many revisions resulting in death.

b) Mobility.

	Method used.
A	Long calipers/elbow crutches;wheelchair by 13y.
B *	Independently ambulant.
C *	Long calipers/crutches; wheelchair by 13 years.
D	Long calipers/crutches; wheelchair by 9 years.
E	Wheelchair.
F	Long calipers/crutches; wheelchair by 13 years.
G*	Ambulant but unsteady gait;wheelchair for school use at 13 years as easier in mainstream school.
H	Long calipers/crutches; wheelchair by 13 years.
I	One short leg splint/crutches with wheelchair use at times.

* the three children who could be classified as average or above in mathematics.

Table 5. A comparison of the percentile ranks of the nine children on Raven's Progressive Matrices and the Crichton Vocabulary Scale, 1978-84.

Child	Test	1978	1979	1980	1984
A	Raven	50	10-25	25	70
	Crichton	25-50	25-50	10	40
B*	Raven	50	50	50-75	65
	Crichton	+95	90	90	75
C*	Raven	50	50	90	70
	Crichton	90	90	95	70
D	Raven	5	5	10	>5
	Crichton	75-90	50-75	50	40
E	Raven	25	25-50	10-25	5
	Crichton	80	50-75	50	55
F	Raven	25	25	25-50	50
	Crichton	50-75	50-75	50-75	50
G*	Raven	75-90	90	90	95
	Crichton	95	95	95	95
H	Raven	5	10	>5	>5
	Crichton	>5	>5	>5	>5
I	Raven	25	10	Died	
	Crichton	5	>5		

* The three children who could be classed as average or above in mathematics.

Intellectual ability.

The child's intelligence is likely to be a major factor in the level of performance in any school subject and Tew(1983) suggests that low general intelligence is a prime cause of poor mathematical ability. Raven's Coloured Progressive Matrices and the Crichton Vocabulary Scale were used to get a rough idea of the intellectual level of the children, with other tests, as stated earlier, being used to back up this information.

Fulthorpe(1973) had worked out rough IQs based on Raven's Matrices and found his results very much in agreement with those of other researchers such as Lorber(1971), whose report was based on results from the Stanford-Binet Test. Tew(1983) found a high correlation(-0.87) between scores on the Bender-Gestalt Test and the WISC. These findings would suggest that the former could also be deemed to be useful as a guide to intelligence levels.The Frostig Developmental Test of Visual Perception could be used in a similar way. Tew(1983) stated that the results on this test depend greatly on the child's level of general intelligence and in fact had found a high correlation between scores on the Frostig Test and the WPPSI at the age of five. The early assessment of intelligence made by people such as medical officers and nursery school teachers tended to be on the optimistic side. At this early age none of the children was described as being below average and it is likely that this is due to their early verbal fluency being misleading(Swisher and Pinsker 1971).

The results will be considered in the groups that were drawn up based on ability in mathematics. Table 5 gives a comparison of the percentile ranks for all the children on Raven's Coloured Progressive Matrices and the Crichton Vocabulary Scale. Table 6 gives comparative results on the Frostig Developmental Test of Visual Perception and the Bender-Gestalt Test for 1978 and 1980.

Children B, C and G.

These three children, who could be classed as average or above in mathematics, did not fall below the 50th percentile on either the Raven's Coloured Progressive Matrices or the

An illustration of the poor visuo-spatial abilities of the children in the main case studies.

	Chronological Age 1978	Chronological Age 1980	Bender Age 1978	Bender Age 1980	Bender Indicators of brain damage 1978	Bender Indicators of brain damage 1980	Frostig Perceptual Quotient 1978	Frostig Perceptual Quotient 1980	Frostig Age equivalents Subtest 1. 1978	Frostig Age equivalents Subtest 1. 1980	Frostig Age equivalents Subtest 2 1978	Frostig Age equivalents Subtest 2 1980	Frostig Age equivalents Subtest 3 1978	Frostig Age equivalents Subtest 3 1980	Frostig Age equivalents Subtest 4 1978	Frostig Age equivalents Subtest 4 1980	Frostig Age equivalents Subtest 5 1978	Frostig Age equivalents Subtest 5 1980
Child A	8yrs. 1mth.	9yrs. 8mth.	5yrs. 2mth.	5yrs. 6mth.	12	10	73	72	6y.	6y3m.	4y6m	6y6m	8y3m	9y *	6y3m	7y	6y6m	7y6m
Child B	7yrs. 8mth.	9yrs. 4mth	6yrs. 4mth.	6yrs. 6mth.	6	6	89	92	7y	10y	8y3m *	8y3m *	8y3m	9y *	6y3m	5y6m	6y6m	8y3m *
Child C	7yrs. 2mth.	8yrs. 10mth.	7yrs. 3mths	+11yrs.	3	0	97	92	7y	7y	5y9m	7y.	7y6m	9y. *	7y6m	8y9m *	8y3m *	8y3m *
Child D	7yrs. 9mth.	9yrs. 5mth.	5yrs. 2mth.	5yrs. 5mth.	9	11	-65	70	4y9m	5y9m.	4y3m	4y9m	5y6m.	6y3m	4y9m	5y6m	6y	5y6m
Child E	7yrs. 8mth.	9yrs. 4mth.	6yrs. 6mth.	7yrs. 3mth.	5	4	90	80	9y6m	7y	5y3m	7y	7y6m	9y *	5y6m	6y3m	6y6m	8y3m *
Child F	7yrs. 7mth.	9yrs. 3mth.	10yrs. 9mth	8yrs. 1mth.	1	4	85	86	6y9m	10y	5y9m	8y3m. *	6y9m	7y6m	6y3m	8y9m *	7y6m	7y6m
Child G	7yrs. 5mth	9yrs. 1mth	10yrs. 9mth	+11yrs.	0	0	121	98	+10y *	8y6m	8y3m *	8y3m *	9y *	9y *	7y	8y9m *	8y3m *	8y3m *
Child H	7yrs. 7mth.	9yrs. 3mth.	-5yrs.	-5yrs.	15	14	-65	58	4y9m	6y	3y	4y9m	3y6m	7y	4y9m	5y	4y9m	5y.
Child I	8yrs.	1979. 8yrs 3mth.	6yrs. 6mth.	1979. -5yrs.	5	1979. 15	69	1979. 78	5y9m	6y3m	5y3m	7y	6y3m	9y *	5y6m	7y	6y	7y6m

Child I } at C.A. 8yrs. 8mth. had a Bender Age of 7yrs. 3mth. with 4 indicators of brain damage } Valve operation just after 1978 testing
at C.A. 9yrs. 3mth. had a Bender Age of 7yrs. 3mth. with 5 indicators of brain damage. } and died shortly after the last testing.

Children C and G had Bender Ages better than their Chronological Ages on both occasions. These children succeeded at maths.

The top age equivalent scores on the Frostig test are:- +10y / 8y3m / 9y / 8y9m / 8y3m. Marked *.

The Children C and G performed best on the Frostig Test. Child B, who ranked next in maths performed fairly well.

Table 6.

Crichton Vocabulary Scale. Their scores on Raven's Matrices were superior to those of any of the other children, although there were other children who scored in the same range on the Crichton Vocabulary Scale. Within this group of children who made good progress in mathematics the percentile ranks on Raven's Matrices improved over the years of the study, suggesting that some perceptual deficits may exist in the early years of even the most able children, but can be made up in time. In the early part of the study their verbal skills as shown on the Crichton Test were better than their non-verbal skills as shown on Raven's Matrices. This difference became less throughout the study due to their improvement on the latter test, with their verbal skills remaining consistently good. The 1984 follow up results raise the suspicion that in the case of the children B and C, the verbal skills had fallen back slightly towards average. However, as this test has limitations above the age of eleven years these results must be treated with caution.
Of the three children in this group two of them, C and G, gained better results on the Frostig Developmental Test of Visual Perception and the Bender-Gestalt Test than the other children, in both 1978 and 1980(Table 6). The third child obtained results within the normal range on the Frostig Test but performed very poorly on the Bender-Gestalt Test on both occasions. He was the weakest of this group in mathematics and it seems likely that he was of rather lower general intelligence. By 1984, at the age of thirteen, he also showed no errors on the Bender-Gestalt Test and scored at the top of the scale.
It would seem that this group were aided in the development of mathematical concepts by having a higher level of general intelligence than the rest of the group. Although they showed slight evidence of visuo-motor deficits in comparison to their verbal skills they were nevertheless performing within the 'normal' range in this area. In addition this group did not contain the most severely handicapped children. None of them had had shunt problems and two of them were independently ambulant.

Children A, D, E and F.

Three of these children(D,E.F) had good verbal skills, as shown on the Crichton Vocabulary Scale,and were poor at mathematics. They did not show any improvement in their percentile rankings on Raven's Matrices throughout the study. In fact Child E dropped down to the 5th percentile in this area. This was a child with a thoracic lesion , who had her shunt removed in the first year as being unnecessary. However her psychomotor development cannot be said to have progressed normally so some degree of continuing Hydrocephalus may be suspected(Milhorat 1972). All three of these children dropped back in terms of percentile rankings on the Crichton Vocabulary Scale although they did not drop below the 50th percentile.

Child A fell into the slightly below average range on the Crichton Vocabulary Scale and was consistent apart from a lower result in 1980. On Raven's Matrices he showed more variation, both above and below the 50th percentile. His final score at the 70th percentile occurred in the same year(1984) that he showed no errors on the Bender-Gestalt Test. Child E also scored at the top of the scale on this test in 1984, but Children D and F did not, with Bender ages of 8year 1 month and 10 years 9 months respectively. Child D still made errors said to be indicative of brain damage and was the only one of this group to perform very poorly on the Draw-a-Man Test,in the early part of the study. Her drawing placed her at the 3rd percentile and can be seen in Appendix 3.

Care must be taken in interpreting the results from the Bender-Gestalt Test as the Koppitz norms are based on children in the United States and it has been suggested they may not be accurate for British children. Broadhurst and Phillips(1969) found their sample in Birmingham to be roughly six months lower than the norms given for children of their age.

The results of these children on the Frostig Developmental Test of Visual Perception suggest that there are general weaknesses in visual perception among these children.

This is consistent with the findings of Miller and Sethi (1971), Badell-Ribera et al.(1971) and Anderson and Spain

(1977) who suggested that the intellectual deficit in these children is likely to be visuo-spatial rather than global. The children D, E and F seem to illustrate this best although even in the group of children who were good at maths the verbal skills tended to be superior to the non-verbal. Although three of these children showed above average verbal skills in the early years of this study these were not supported by equivalent non-verbal skills and it seems likely that this is partly responsible for their difficulty in developing mathematical concepts. The spatial elements involved in developing basic ideas of conservation and other mathematical concepts may contribute to the problem. It is possible that the poor results on the visuo-spatial tests reflect the neurological damage which is likely to be present in children with shunt-treated Hydrocephalus. Straus and Lehtinen (1947) point out that such children are likely to have problems in such areas as distinguishing figure from ground which would affect results on both the Frostig and Bender-Gestalt Tests. Even Raven's Matrices could be affected but the use of colour in this test should result in less problems.

It is likely that the teachers of these children have been misled by their good early verbal skills and have started formal maths before the children had grasped the necessary pre-number concepts.

Children H and I.

These two children performed poorly on all the tests which leads to the conclusion that they were both of low general intelligence, with their results in mathematics being primarily related to this fact. Even by 1984 Child H had a Bender age of only 6 years 4 months and still showed 7 indicators of brain damage. Child I showed great fluctuations in scores on the Bender-Gestalt Test following surgery involving her shunt which suggests that the child's brain is sufficiently plastic to recover from such insults to some extent.

Additional case studies.

Some additional case studies were carried out and the results are shown in Appendix 2. One child's results were of particular interest in the consideration of the development of verbal skills and their relationship to the development of mathematical abilities. This child(Child vi) performed very much better on Raven's Matrices where she scored at the 50th percentile, than on the Crichton Vocabulary Scale where she scored at the 5th percentile. She came from a deprived linguistic background and required speech therapy when she started school. After this she made rapid progress in this area. It is interesting that in 1979, at the age of 9 years 7 months, she had a far more even profile of skills in the basic subjects than the other children. She had both maths and reading ages of 8 years 4 months. It can be postulated that this may be because her language related skills were not in advance of her other skills at an early age, but care must be taken not to make generalisations from the results of individual children.

A brief comparison of findings on this test battery with those of Parfitt(1979).

In his study of the relationship of the development of mathematical concepts to the development of conservation in children with Spina Bifida, Parfitt used a battery of tests similar to those used in this study.
Although the numbers involved in this study were very small the findings show some similarities to those of Parfitt who found that his sample of Spina Bifida children were marginally above average on the Crichton Vocabulary Scale at five years old, average at six to eight years old and then dropped back.
He also found that they performed at a lower level on Raven's Coloured Progressive Matrices than on the Crichton Vocabulary Scale.
Using the Bender-Gestalt Test he found that at 9½ years of age his sample of 90 children with shunts had a mean Bender age of 5 years 3 months. The deficit found in the case study children at the same age was very similar. Apart

from two children who had Bender Ages above their chronological age in both 1978 and 1980 those of the other children became further divorced from their chronological age between the two testings . The deficits ranged from one to three years in 1978 and up to four years by 1980. However it was heartening to find that by 1984 five of the eight survivors scored at the top of the scale on this test which suggests that improvement may continue at a later than normal age. Parfitt(1979) had found that mathematical concepts developed at a later than normal age although the results of this study do not show a similar definate improvement. However with only eight survivors, three of whom performed well in maths, it is not possible to make generalisations, although they did show improvements in reading up to the age of thirteen as Parfitt had found.

Summary of the main points from the school based research.
Part 1. Results on the Young Group Mathematic Test.

The results in this section confirmed the belief that many children with Spina Bifida and Hydrocephalus have a weakness in the area of mathematics. In the original testing in 1976 the 19 children with Spina Bifida were consistently poorer than the 49 other children, who were made up of 15 with Cerebral Palsy and 34 with disabilities where no neurological damage would be expected. The children with Cerebral Palsy scored lower marks than those with other disabilities but were not as low as those with Spina Bifida. The children with Spina Bifida seemed to be able to cope with the basic process of counting but failed when an understanding of the concepts involved was required.

In the group studied in 1978, which consisted of 11 children with Spina Bifida and 14 with other disabilities there was very little difference between the groups with the maths scores being generally low. The children with Spina Bifida performed similarly to those studied in 1976 but the difference lay in the group of children with other disabilities, with those studied in 1976 performing at a higher level. Although the samples were small and care must be taken in interpreting the results, the difference would appear to be in the number of neurologically damaged children in the group of 'other disabilities'.

In 1976 only 15 out of 49 children had some element of neurological damage whereas in 1978 10 out of 14 were of this type.

Thus it would seem that children with neurological damage are likely to have problems in developing mathematical concepts, and these findings would suggest that one of the main factors affecting the children with Spina Bifida is the neurological damage associated with the Hydrocephalus. That this is not a simple cause and effect relationship will be discussed in a consideration of the large scale data from Sheffield which sheds further light on this matter. It is possible that one of the concomitants of such damage is problems of concentration which can have a severe effect on the development of mathematical concepts (Strauss and Lehtinen 1947).

Part 2. Case Studies.

As there were only nine children in the main group studied in detail it was felt inappropriate to carry out statistical analysis on the results. They can, however, be used to discuss general trends, although care must be taken not to make unwarranted generalisations.

The following trends were shown by the case studies:-

1) The intellectual ability of these children tended to be overestimated at the pre-school and nursery school level. This may well be the result of their early development of language skills which can give the superficial appearance of intelligence. Menelaus(1980) and Zeiger and Orgel(1969) comment on this misleading early verbal ability.

2) The children who were of average ability, or above, in mathematics all scored in this range on both verbal and non-verbal tests. Tew's(1983) suggestion that general intelligence is a major factor in the development of mathematical concepts is supported. An IQ in the normal range may well be a necessary, but not a sufficient, condition for the development of mathematical concepts and it seems likely that the verbal and non-verbal sides of intelligence need to be within this range. Three children who had high verbal scores were poor at maths. They also had below average scores on the non-verbal tests.

3) The infant school reports of the children stated that they were all progressing on a formal maths scheme. The later findings in mathematics would suggest that in many cases they had started too early and were trying to base mathematics on the appearance of pseudo-counting at an early age.

4) Parfitt's findings that Spina Bifida children can develop number concepts related to their development through the stages suggested by Piaget, is supported to some extent by these findings. The children who succeeded in conservation tests early in the study were those who performed well at maths and the children who did not show conservation performed poorly.

5) Reading seems to be an easier skill for these children to acquire than mathematics and by the age of thirteen years six of the eight surviving children were performing

at or above their chronological age in reading whereas in maths only three scored at the top of the scale in the Young Group Mathematics Test. This scale only goes up to 9.9 years.
Similar results were found by Tew and Laurence(1972) who found 37.5% of their sample to be between one and four years behind their chronological age in reading compared to 78% who were that far retarded in maths.
6) With a small group of only nine children it was not very meaningful to subdivide them on the basis of mobility. However only two children fell into the independently ambulant category and both of these were in the group of three who performed at an average level or above in mathematics. These children were both transferred to main-stream school at the age of thirteen, with transfer not merely related to their academic ability but also to their mobility.
7) All the children in this part of the study were shunted but the five children who had had no shunt problems included the total group of three children who were successful at mathematics. It is possible that shunt-treated Hydrocephalus is compatible with normal intellectual development but that the need for revision can cause problems.

As firm conclusions cannot be drawn from such a small sample large scale data from Sheffield Children's Hospital was also considered. This gave the opportunity to investigate far more variables, some of which rely on clinical data which is not available within a school. Variables which appeared to be related to the development of mathematical concepts and needed further investigation following the school based research were:-
a) Intellectual development, including both verbal and non-verbal skills.
b) Mobility and severity of physical handicap.
c) Neurological damage related to Hydrocephalus.
d) School placement.
These are looked at in the next chapter.

CHAPTER SEVEN.

An investigation of factors which may be linked to mathematical performance in children with Spina Bifida, using large scale data from Sheffield Children's Hospital.

Part 1. Materials and methods.

Consideration of the four arithmetic ability groups.

It must be emphasised that the Arithmetic Quotients referred to in this Chapter have been worked out approximately from the scale scores on the arithmetic sub-test of the WISC. This may not be very accurate as there is no claim made for the sub-test to stand as an arithmetic test in its own right.

A study of large scale data from Sheffield Children's Hospital.

Materials and methods.

A study was carried out using information from the data bank on Spina Bifida children at Sheffield Children's Hospital. These children were mostly drawn from the counties of Yorkshire, Derbyshire, Nottinghamshire, Leicestershire and Lincolnshire and had been treated either initially or on later referral at Sheffield, which became established as a centre for the treatment of Spina Bifida and Hydrocephalus in the late 1950s. The purpose of the study was to see if findings from a large scale analysis of data could provide any information on the possible reasons for the problems shown by these children in mathematics.

The data was analysed at the University of Manchester Regional Computer Centre using Version 7 of the Statistical Package for the Social Sciences(Nie et al. 1975).

Firstly a univariate analysis(Analysis 1) was carried out using a wide range of criterion variables, broken down by groups according to ability in arithmetic as assessed by the scale score on the arithmetic sub-test of the Weschler Intelligence Scale for Children. There were four groups:-

<u>Group 1</u>. Those with scale scores of 1 - 4. N = 70.
<u>Group 2</u>. Those with scale scores of 5 - 7. N = 179.
<u>Group 3.</u> Those with scale scores of 8 - 12. N = 281.
<u>Group 4.</u> Those with scale scores of 13- 19. N = 70.

The mean of each sub-test on the WISC is in the region of 10 with a Standard Deviation of 3 which means that Group 3 almost covers all those within one Standard Deviation of the mean. This can be roughly considered to be the average range. Data was analysed for 600 children but inevitably certain measures were missing for some children and hence they are not all represented in some of the analyses. For instance only 126 were included in a consideration of the extent of the lesion and 207 in the ventricle-brain ratio analysis.

In addition to the analysis of variance tables a correlation matrix was produced giving Pearson's product moment correlation coefficients.

As these analyses showed that diagnosis and degree of handicap were very highly correlated with arithmetic scores and it seemed that the top two arithmetic groups contained most of the children with meningocele, thus making these groups not really clinically comparable with the others, a second analysis(Analysis 2) was carried out. This was also a univariate analysis using the SPSS version 8(1975) with the arithmetic groups broken down into Myelomeningoceles with and without shunts and Meningoceles.

In order to gain some insight into the role of Hydrocephalus in the problems a similar analysis was carried out for children with congenital Hydrocephalus. This was used for comparative purposes.

In Analysis 2 the significance of the difference between the means for the groups based on diagnosis was tested using a 't' test which was carried out manually(Crocker1969). There were in fact only 43 Meningoceles in total, distributed as follows:-

Group 1. 1 Meningocele out of a total of 77 children.
Group 2. 2 Meningoceles out of a total of 185 children.
Group 3. 27 Meningoceles out of a total of 263 children.
Group 4. 13 Meningoceles out of a total of 69 children.

Full details of the distribution of the different diagnoses are shown in Table 8, later in the Chapter.

The methods used to obtain the measures by medical and psychological staff of the hospital.

Reading Quotients.

These have been worked out from the Schonell Graded Word Reading Test(1950) with the quotient obtained from the Reading Quotient formula:- $\frac{\text{Reading Age}}{\text{Chronological Age}} \times 100$.

This test gives a measure for mechanical reading for children of above five years of age. The reading age is obtained by dividing the number of words correctly read by the child by 10, and adding 5 years.

Intelligence Quotient.

The majority of the children were tested on the Weschler Intelligence Scale for Children. Those outside the age range for that test were assessed on the Weschler Pre-School and Primary Scale of Intelligence or the Weschler Adult Intelligence Scale. In a few cases other tests were used and care needs to be taken over comparisons of IQs from these tests. e.g.The Vineland social maturity scale which is not strictly an IQ measure.

Weschler tests were used because they give a profile of skills including both Verbal and Performance Quotients, as well as a full-scale IQ. The quotients have a mean of 100 and a standard deviation of 15. The arithmetic test used to define the groups is one of the sub-tests on the verbal part of these scales.
Correlations between the arithmetic test and the Verbal IQ range from .62 at the age of $8\frac{1}{2}$ years to .78 at the age of $6\frac{1}{2}$ years (Weschler 1976).

Clinical measures.

Diagnosis.

The diagnosis was made by a consultant paediatrician.

Brain Scans.

These were carried out at varying ages but normally near the time of intelligence testing, often on the same day for convenience. They were not carried out at birth.
The CT 1010 machine was used to produce a series of scans covering the whole brain by 13mm. slices. The slice used for measurement was the one where the ventricles were the largest which was usually scan 2a. That is conventionally the third slice 26-39mm. above the supra-orbitomeatal line (along a line from the eye to the ear).
The area of the ventricle(V) was measured by manual planimetry and the area inside the skull(B) measured to give a ventricle-brain ratio rating:- $\frac{V}{B} \times 100$.
An electronic device is now available for doing this which is a much quicker method.
Some children were found to have irregular scans such as those with porencephalic cysts, which may be the result of ventricular taps in infancy, or Dandy Walker syndrome which is a cystic condition of the occipital lobe sometimes found in Hydrocephalus.

Head circumference at birth.

The measurement given is the maximum occipito-frontal circumference measured with a tape measure within a few hours of birth.

Thickness of cortex at birth.

This was worked out using air ventriculography by means of lateral skull ventriculograms. The distance from the roof of the lateral ventricle to the inner surface of the skull is measured on the X-ray which is life size.

Location and extent of lesion.

This was found by X-ray of the spine which gives the radiological level of the lesion and its extent.

Shunt.

The presence of a shunt was recorded and is now generally accepted as the best guide as to whether Hydrocephalus is present. However this is not always the case as they have been inserted unnecessarily in some children. For this reason some cases, particularly mild ones,were given isosorbide which is an osmotic, diuretic drug(Lorber 1972). This causes urination and reduces the body fluid level and thus the production of cerebro-spinal fluid. As yet it has not been used in a large number of cases so results are not conclusive although it seems to be a useful way of avoiding unnecessary surgery in some cases.

Locomotion.

A crude index of wheelchair, calipers or no aids was used but many children combine the first two methods for part of a day. They may well turn up at the hospital on calipers and crutches but resort to a wheelchair much of the time at home and at school. The number of children in the wheelchair group may therefore be an underestimate.

Continence.

Only urinary continence was considered and it is necessary to remember that a lot of children with sacral lesions are incontinent although in other ways they may appear normal.

Table 7 .(Analysis 1)

The means or general statements deduced from the data for all four arithmetic sub groups.

	Group 1			Group 2		
	Mean	N	SD	Mean	N	SD
Year of birth	66-67	70	4.4	65-66	179	4.4
Age at test	9.3yr	70	3.9	10.2yr	179	4.3
Verbal IQ	70	70	11.8	84	179	11.0
Performance IQ	59	69	11.9	76	178	15.1
Full scale IQ	62	69	11.2	78	178	11.1
Reading Quotient	67	62	14.8	78	161	17.8
Approx.Arith. Quotient	65	70		76	179	
Arithmetic Scale scores	3.1	70	1.1	6.0	179	.82
Head circ. at birth	352mm	59	31.1	348.5mm	143	21.1
Ventricle brain ratio	44.2%	8	9.4	34.3%	60	16.2
Thickness of cortex	18.8mm	51	6.9	20.9mm	112	5.9
Valves %	87%	68		66%	176	
Locomotion	Majority W/C	70		Majority W/C	178	
Incontinent of urine	82%	68		84%	174	
P.H.School	85%+	70		80%	177	
Diagnosis	Mostly Mmc.	70		Mostly Mmc.	179	
Location	Many with T	68		Many with T	171	
Extent (vertebrae)	7.56	16	2.1	6.0	36	2.5

Mmc - Myelomeningocele T - Thoracic

Table 7. (Analysis 1)

The means or general statements deduced from the data for all four arithmetic sub groups.

	Group 3			Group 4		
	Mean	N	SD	Mean	N	SD
Year of birth	67-68	281	3.9	68-69	70	3.9
Age at test	8.2yr	281	3.5	7.5yr	70	3.1
Verbal IQ	102	281	12.5	120	70	13.5
Performance IQ	86	281	13.2	97	70	14.9
Full scale IQ	94	281	12.5	110	70	11.9
Reading Quotient	92	239	15.7	110	61	19.6
Approx.Arith. Quotient	100	281		120	70	
Arithmetic Scale scores	9.8	281	1.2	14.4	70	1.4
Head circ. at birth	348.9mm	228	23.7	346.3mm	54	18.9
Ventricle brain ratio	29.7%	105	16.5	27.4%	34	16.7
Thickness of cortex	21.8mm	182	6.7	24.6mm	39	6.6
Valves %	59%	280		46%	70	
Locomotion	W/C & Ambulant	281		Majority Ambulant	70	
Incontinent of urine	69%	274		64%	69	
P.H.School	56%	278		28%	69	
Diagnosis	More Mc.	281		Mostly Mc.	70	
Location	More L&LS.	272		More L, LS&S.	68	
Extent (vertebrae)	6.29	52	2.3	5.90	22	2.3

Mc - Meningocele L - Lumbar S - Sacral

A profile of each arithmetic sub-group.

The means or general statements deduced from the data for all four groups can be found in Table 7. (Analysis 1)

Sub-group 1.

This is the group with WISC arithmetic sub-scale scores from 1 to 4 with a mean of 3.1. This gives a very rough arithmetic quotient of 65.

The profile of WISC sub-scale scores for this group is shown in Figure 28. The weakest areas were arithmetic and coding with the latter falling slightly below arithmetic. Coding involves the skill of visual memory but is also a test of hand speed which may be expected to be poor in this group of children who also show up as being the most handicapped physically.

The test of object assembly was the one nearest to arithmetic in terms of scores and this involves putting together jigsaws of familiar objects. The mean for this test was 3.4 compared to 3.1 for arithmetic. It is interesting that Straker(1983) suggests that children who show a great interest in jigsaws may be potentially good mathmeticians.

The most successful areas for this group were two of those on the verbal scale, similarities and vocabulary, with the latter even falling within one Standard Deviation below the mean. Thus in dealing with these children the vocabulary is likely to stand out as good and may well suggest better verbal skills than actually exist overall.

The verbal and performance IQ means differ by 11 points but this is less than Weschler(1974) states as being significant. According to Anderson and Spain(1977) the children with their overall Intelligence Quotient below 80 are likely to have the greatest discrepancy between their verbal and performance scores. This is not supported here since the best group, based on the arithmetic sub-scale scores, has a mean IQ of 110 with a 23 point discrepancy between the two scales. The two bottom groups have the least discrepancy. This does fall into line with the findings of Dennis(1981) and Tew(1983) who comment that as the overall IQ increases the differences between the verbal and performance scores increase. Tew(1983) however had not found significant differences in his South Wales study

WISC profiles for the arithmetic sub-groups .

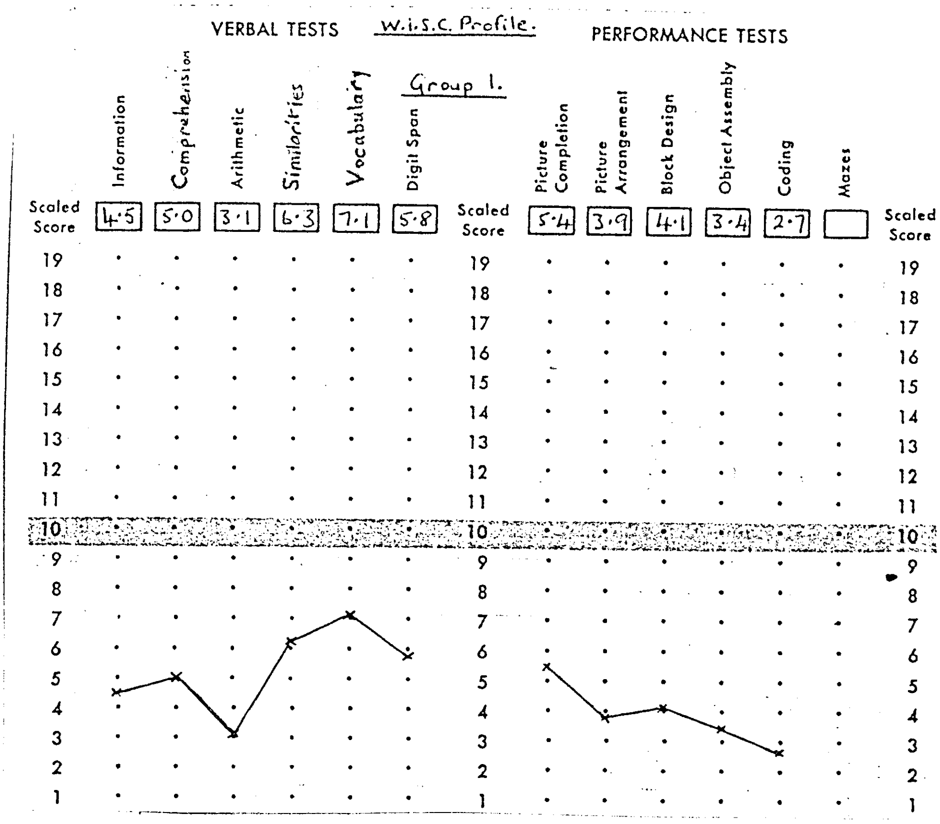


Figure 28. Group 1.

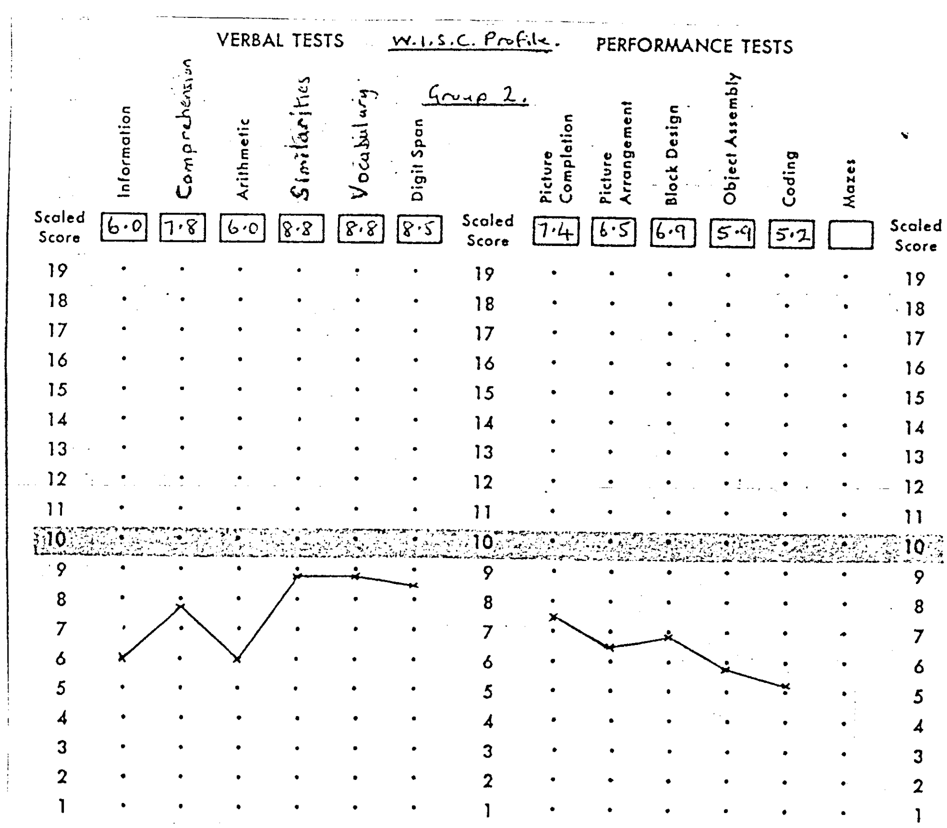


Figure 29. Group 2.

Lonton (1982) lists criteria associated with a mean IQ of less than 80. Of these criteria three are certainly supported here. These are:-

a) Thoraco-lumbar or thoraco-lumbar-sacral lesions.

b) Wheelchair dependency.

c) Neonatal pallium below 20mm.

His other two criteria, involvement of 9 or more vertebrae and a head circumference of more than 390mm. or less than 310mm. at birth may well apply to part of the group but are not supported by the mean. These criteria will be looked at again in connection with group 2 which also has a mean I Q of below 80.

Thus in conjunction with the low mean arithmetic score there are generally low scores on all areas of the WISC with only vocabulary falling within the normal range. The mean reading quotient is very similar to the mean verbal I Q. Physically the children are severely handicapped, largely Myelomeningoceles, a considerable number of whom have thoracic involvement. At least 85% are in schools for the physically handicapped and are incontinent, wheelchair bound and with shunt-treated Hydrocephalus. The mean ventricle-brain ratio at 44.2% is high considering that 10-20% would be considered normal, (Lonton 1982) and the mean neonatal pallium is thin(18.8mm). More vertebrae are involved than in any other group. These children are among the oldest in this sample and are unlikely to show much effect from selection which in Sheffield began in 1972.

Sub Group 2.

This is the group with W I S C arithmetic sub scale scores from 5-7 with a mean of 6.0. This gives a very rough arithmetic quotient of 76.

The profile of W I S C sub scale means is shown in Figure 29.

The weakest area of this group on the sub scales was coding with a mean of 5.2, with arithmetic, information and object assembly all being within 0.1 of each other. It is interesting that arithmetic, object assembly and coding were also the 3 weakest areas in group 1. The

strongest areas for this group were similarities and vocabulary which again match those of Group 1.
The discrepancy between the verbal and performance I Qs in this group is less than for any of the others with the difference being only eight points. As with Group 1 this does not confirm the findings of Anderson and Spain (1977) that the discrepancy is greatest in those children with an overall I Q of below 80. This group is the oldest on average and may be starting to show the dropping back of verbal I Q as the child gets older, after the good early verbal development. This will be considered later for the four groups together.
This group shows slightly less of Lonton's (1982) adverse criteria for intellectual development although in terms of thoracic involvement and wheelchair dependency it is very similar. The thickness of the neonatal pallium is only just over the 20mm. suggested as being the minimum for normal intellectual development, but the mean number of vertebrae involved is only 6 which is less than in Group 1. The mean reading and arithmetic quotients are very similar to the mean I Q scores.
Physically the children are not quite as handicapped as Group 1 although many are Myelomeningoceles, 66% of whom have shunts . Slightly less of this group are in wheelchairs and 84% of the group are incontinent.The ventricle brain ratio is 10% less than Group 1 although at 34.3% it is still high. 20% less children have shunts than in Group 1 which would suggest a lower incidence of Hydrocephalus. As this is the oldest group (mean age 10.2 years) they are not likely to show much effect of selection which began in 1972. The results may be influenced by the fact that of children born before 1958 when the shunt for Hydrocephalus was introduced, only the milder cases survived.

Sub Group 3.

This is the group with W I S C arithmetic sub scale scores from 8-12 with a mean of 9.8 and a rough arithmetic quotient of 100. These arithmetic scores are within one Standard Deviation from the test mean so it would be

WISC profiles for the arithmetic sub-groups.

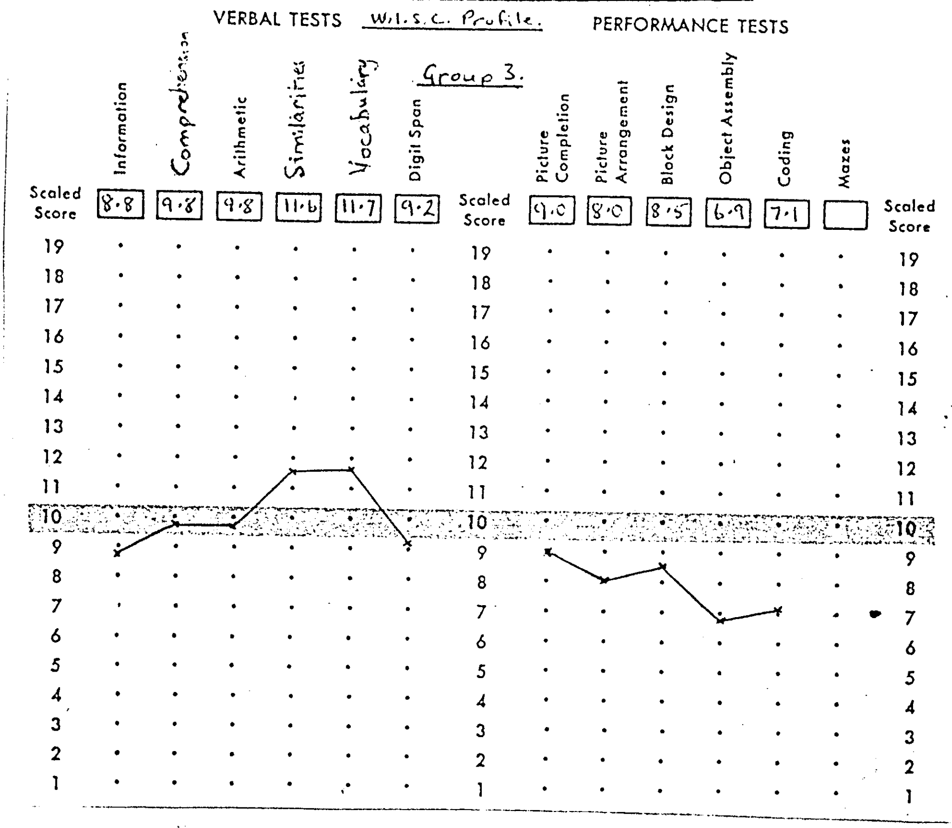


Figure 30. Group 3.

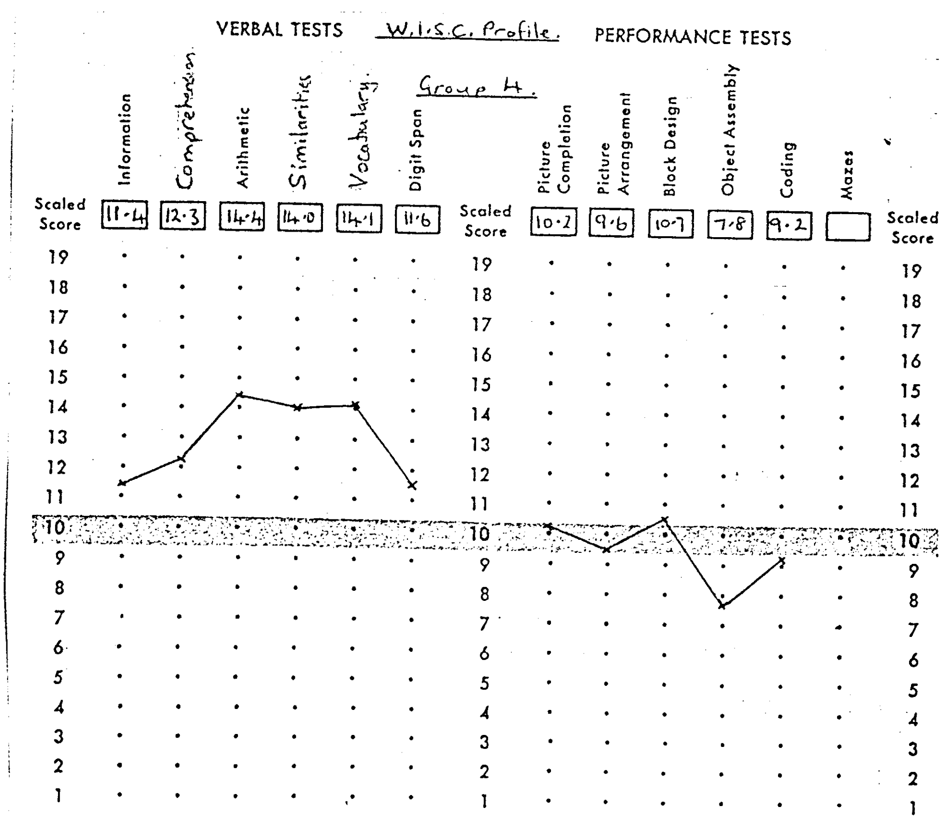


Figure 31. Group 4.

expected that other sections of the WISC would fall into the same range. The profile of sub-scale scores is shown in Figure 30.

In fact all the quotients and the sub-scale scores with the exception of object assembly fall within one Standard Deviation of the mean. Object assembly is just below and coding just inside. As with the two poorer groups vocabulary and similarities are the strongest areas.

The discrepancy between verbal and performance IQs for this group is 16. This is a higher figure than that shown by either of the previous two groups. This may be expected because the overall scores are higher but there is a possibility that the discrepancy may also be linked to age. This group is younger than the two previously considered and as has already been suggested the discrepancy may be greater in younger children.

Physically these children are less severely handicapped with the group containing a greater proportion of children with Meningocele,and ambulant children. Only 59% of this group have shunts for Hydrocephalus. The ventricle-brain ratio is down to 29.7% and 69% of the children are incontinent. It is likely that this group is starting to show the effects of selection which began in 1972, resulting in physically and mentally more able children, the latter however still being very difficult to predict(Lonton 1982).

<u>Sub Group 4.</u>

This is the group with WISC arithmetic sub-scale scores of 13 and above with a mean of 14.4 and a rough arithmetic quotient of 120. These arithmetic scores are at least one Standard Deviation above the test mean. The only other scores falling this much above the mean are those for similarities, vocabulary and the verbal IQ. The two sub-tests are the same ones in which the other groups gained their best results. The weakest area is object assembly which at a mean scaled score of only 7.8 just falls into the normal range. This is an area which is very weak in all four groups.

The discrepancy between verbal and performance IQ is highest in this group being 23 points, with a mean IQ of 110. This is the youngest group with a mean age of 7.5 years. Physically this group is the best with the majority of the children being ambulant by some means and a number of the lesions being Meningoceles. The lesions tend to be less extensive in this group. 46% of the children have shunts and the mean thickness of the cortex is 24.6mm. which is an increase of 2.8mm. on Group 3 and 5.8mm. on Group 1. The ventricle-brain ratio is the lowest of the groups at 27.4%. There is still a high incidence of incontinence at 64%. Many of those with sacral lesions are incontinent but apart from that are minimally handicapped.

The profiles for the four arithmetic groups suggested that there was a considerable difference physically between the children who were more or less able, with diagnosis being an important factor. Table 8 shows the actual distribution of children with Meningocele, as considered in the second analysis. Due to the fact that the numbers are low, being only 43 out of a total of 594, they do not make up the major part of any arithmetic group, but the gradient works from them forming only a very small percentage of the lower groups(less than 2%) to form 10% and 18% of the top two groups respectively. The children with Myelomeningocele and shunts are distributed the opposite way forming 83% of the bottom group and only 40% of the top group despite their greater numbers.
The gradient for the Myelomeningoceles without shunts also goes in the same direction.
When it is looked at from the point of view of the percentage of children with each of the three diagnoses in each of the arithmetic groups there is a clear distinction. The highest percentage of all the diagnoses falls in Group 3 which covers the normal range of scores and is where the majority of children would be expected to fall. However there is a considerable difference in the size of the percentage, being 62.8% for the Meningoceles and only 40.4% and 47.6% for the Myelomeningoceles with and without shunts respectively.
Further consideration will be given to these variations in the following discussion of separate variables in the analysis.

Table 8. (Analysis 2)

Tables to show the distribution of the children with meningocele, and myelomeningocele with and without shunts.

a) The percentage of each arithmetic ability group drawn from each diagnosis.

Diagnosis	Group 1	Group 2	Group 3	Group 4
Myelomeningocele with shunt N=364	83.1% N=64	67.6% N=125	55.9% N=147	40.6% N=28
Myelomeningocele without shunt N=187	15.6% N=12	31.3% N=58	33.8% N=89	40.6% N=28
Meningocele N=43	1.3% N=1	1.1% N=2	10.3% N=27	18.8% N=13
Total	100%	100%	100%	100%

b) The percentage of the total number of each diagnosis in each arithmetic ability group.

Diagnosis	Group 1	Group 2	Group 3	Group 4	Total
Myelomeningocele with shunt	17.6%	34.3%	40.4%	7.7%	100%
Myelomeningocele without shunt	6.4%	31.0%	47.6%	15.0%	100%
Meningocele	2.3%	4.7%	62.8%	30.2%	100%

CHAPTER SEVEN - Part 2.

A consideration of the main variables involved in the analysis, taking all the groups together.

A consideration of the main variables involved in the analysis, taking all the groups together.

Two statistics were extracted from the Analysis of Variance table and the Correlation Matrix produced for the data from Sheffield Children's Hospital. These were the Variance Ratio (F) and Pearson's Product Moment Correlation Coefficient (r). If F is significant it indicates that the variation between the groups with respect to a variable is greater than the variation that exists within the groups. In the former case the variation can be attributed to some specified source, in the latter it is considered to be random or chance variation. If r is significant it indicates that the linear relationship between the variables under consideration is at more than a chance level. F and r are given for the WISC Arithmetic sub-scale scores related to the other variables.

Year of birth and age at test in years.

Variance Ratio and Correlation Coefficient with arithmetic.

Table 9	F	P	N	r	P	N
Year of birth	16	0.0001	600	0.24	0.001	600
Age at test	14	0.0001	600	0.21	0.001	600

The data shows a trend towards higher arithmetic scores in children born in later years and in children who were younger when tested. Thus the correlation between arithmetic and age is negative. The high F-ratios indicate that the variation between the four groups, which were based on arithmetical ability, can be attributed to some extent to the different ages of the groups. This improvement in the younger children may be due to the effects of selection. This possibly overrides the effect(for which there is no research evidence but which is a widely held view) in the opposite direction, that of differential deathrate.i.e.the more handicapped children are likely to die earlier. The alternative hypothesis is that maths skills fall off with time. This seems unlikely as research by Parfitt(1979) suggests that children with Spina Bifida and Hydrocephalus develop maths skills later than normal children and go on developing them for longer.

In the four groups, the children in Group 2 are on average the oldest which does not quite follow the trend. It is likely that a number of children of very low intelligence but without the most severe physical handicaps are not being selected out and are still falling into the bottom groups. The findings on diagnosis would support this to some extent and they will be considered later.

Of the total group 9.3% were born before shunt-treatment of Hydrocephalus began in 1958. These children are likely to be the milder cases as they survived without treatment for this aspect of their condition. 76.6% of the children were born after the introduction of shunts and before selective non-treatment began in Sheffield in 1972. 14.1% were born between 1972 and 1979 so are likely to have been considered in terms of selection. This should mean that the majority of the children in this group should be the milder cases.

The ages of the subjects range from three to twenty-five with the mean age at testing being 8.9 years.

It is interesting to consider the correlation coefficients (Pearson's r) for the age of the child at the time of the test with several other variables.

Table 10. Correlations with age at testing.

Variable	r	N	P
Verbal IQ	-0.17	627	0.001
Performance IQ	-0.05	626	NS
Reading Quotient	-0.14	607	0.001
Arithmetic-WISC	-0.21	604	0.001

This suggests that the younger children perform better all round but especially in arithmetic and verbal IQ. Performance IQ seems to be far less related to age although there is a slight tendency towards the younger children gaining better scores. This needs to be considered in the light of the comments made for the individual groups, where the verbal/performance discrepancy is greatest in the most able group which is also the youngest one. The possibility needs to be considered that in the younger children the verbal skills are advanced and drop back relatively as the child gets older(Zeiger and Orgel 1969). However this situation could also be explained by the fact that larger differences are likely when the overall IQ scores are higher(Dennis 1981).

Second analysis.

In the second analysis when the arithmetic groups were subdivided according to diagnosis the findings were still very similar. In all three diagnoses the mean age of those in the top arithmetic group was younger than the others. Although the differences between the groups were highly significant($P=<0.0001$) there were also significant differences ($P=0.01$) shown by the 't' test between the Myelomeningoceles with and without shunts in Groups 2 and 3. In these two groups the mean year of birth of the children with shunts is between eighteen months and two years later than that of the non-shunted children. As was mentioned in the first analysis it seems likely that this reflects the treatment regimes with the older non-shunted children, in Group 2 in particular(mean year of birth 1964), including some from the conservative treatment era. The mean year of birth for all three diagnoses in Group 4 is 1968-9, with the shunted children having a mean year of birth of early 1968 compared with the non-shunted children's mean of mid-1969. These differences were not significant but it seems likely that selection has started to show an effect here. With a standard deviation of 4.2 years for the non-shunted group the year of birth for some will have fallen in the selection period.

Weschler Intelligence Scale for Children (WISC).

Variance ratio and correlation coefficient with arithmetic

Table 11	Mean	N	F	P	r	P
Verbal IQ	95	600	276	0.0001	0.79	0.001
Performance IQ	81	598	106	0.0001	0.61	0.001
Full scale IQ	87	598	254	0.0001	0.78	0.001

The discrepancy between the verbal and the performance IQs for all the groups is noticeable but increased in the more able group which was also the youngest. The verbal IQs fit into the same range of Standard Deviations as do the arithmetic scores. This would be expected as arithmetic is one of the sub-scales on the verbal section. Using these measures the verbal IQ would seem to be a good predictor of ability in arithmetic.

The performance IQs fall into a lower range of Standard Deviations. The range of means is from 59-97 compared to 70-120 for the verbal scale.

Considering the discrepancy between the verbal and performance scores and the fact that arithmetic forms part of the verbal scale it is interesting that the correlation with the performance IQ is fairly high and is significant with P at .001. Arithmetic is one of the weaker parts of the verbal scale for all but the top group and in fact is the weakest area for the bottom two groups.

All of the sub-tests have a high F ratio significant at the 0.0001 level. The peaks and troughs of each group's profile of sub-test scores(Fig.28-31) are very similar despite the varying levels. Similarities and Vocabulary on the verbal scale are the best areas for every group except the top one where Arithmetic is even higher. Consideration has been given to the sub-tests in the group profiles.

It seems possible that the visual perceptual skills are more important in the pre-number and early number period and provided they are good enough to enable foundations to be laid they can then be superceded by verbal skills, which at a higher level involve the use of logical thought rather than the mere empty use of vocabulary.

Table 12.

Correlation coefficients for physical factors and present school with IQ.

All at 0.001 unless stated.

Variable	Full IQ	N	VIQ	N	PIQ	N
Present school	-0.61	936	-0.51	621	-0.56	620
Locomotion	-0.38	949	-0.30	626	-0.43	625
Presence of shunt	-0.33	952	-0.22	621	-0.35	620
Neonatal pallium	0.27	579	0.19	402	0.25	401
Continence	-0.22	935	-0.14	611	-0.21	610
%Ventricle/brain	-0.18	254	-0.12 (P=0.04)	215	-0.31	216
Location	0.15	931	0.17	606	0.24	606
Extent	-0.14 (P= 0.03)	172	-0.20 (P= 0.02)	127	-0.21 (P= 0.009)	126
Diagnosis	-0.11	962	-0.11	627	-0.14	627

Head circumference at birth and hand preference were not found to be significant at the 0.001 level.

The children with the greatest overall intelligence may well be able to counteract their weaknesses, but in the best group, even their weakest areas are only just below the mean(with the exception of object assembly).This seeming change from a need for perceptual skills can be looked at in relation to the developmental stages of Piaget. In the concrete operations stage which generally occurs between 7-11 years the child becomes more systematic in his cognitive thinking. It is likely that the less handicapped child will reach this stage at something approximating the normal time, whereas the more severely handicapped, who will have missed out on experiences in the sensorimotor period, may only reach this stage very late or not at all. Dasen(1972) suggests that even in the most affluent countries less than 100% of seemingly normal adults reach this stage.

Frostig and Maslow(1973) suggest that all the visual perceptual abilities necessary for school success will have developed by 6-8 years of age in the normal child.

The correlation coefficients for physical factors and type of school attended with IQ scores(Table 12) would suggest that severity of handicap has more effect on performance than verbal IQ. It would be reasonable to expect this as the child is likely to have had good opportunities for developing language due to a lot of adult company and the fact that this is an area in which they can perform well early in life. Lack of movement and interaction is likely to have affected the development of perceptual-motor skills which seem to remain depressed at all levels of ability.

The school attended by the child is also related to performance IQ more than verbal IQ and this is likely to be because the most severely handicapped children are the ones left in special schools when the less handicapped are integrated. The correlation between type of locomotion and type of school attended is 0.54 which is significant at the 0.001 level.

In fact as in Lonton's(1981) study the two factors which correlate most highly with type of school are intelligence and locomotion. Continence(0.40), presence of a valve(0.37), thickness of neonatal pallium(0.33) and diagnosis(0.27) are the next highest.

Table 13. Verbal IQ for the three diagnoses, subdivided into arithmetic ability groups.

	Myelomeningocele with shunts			Myelomeningocele without shunts.			Meningocele		
	M	SD	N	M	SD	N	M	SD	N
Group 1	70.6	12.9	64	72.4	9.6	12	45.0	0	1
Group 2	83.0	11.2	125	85.2	10.2	58	93.5	2.1	2
Group 3	99.2	12.8	147	103.6	12.0	89	100.8	15.0	27
Group 4	118.3	13.2	28	120.2	13.8	28	120.4	12.8	13

Table 14. Performance IQ for the three diagnoses, subdivided into arithmetic ability groups.

	Myelomeningocele with shunts			Myelomeningocele without shunts			Meningocele		
	M	SD	N	M	SD	N	M	SD	N
Group 1	59.3	12.5	64	67.1	13.8	11	45.0	0	1
Group 2	73.0	12.6	126	79.0	14.1	58	87.5	2.1	2
Group 3	81.2	12.3	47	90.8	13.0	89	92.2	11.6	27
Group 4	91.1	15.0	28	101.8	14.0	28	102.1	11.4	13

WISC- Second analysis.

There are only a small number of children with Meningocele included in the total study but since only three of these fall into the bottom two arithmetic groups it could reasonably be accepted, as Tew(1983) suggests, that this is a milder condition with a better intellectual prognosis. This view is supported by the fact the first analysis found the lower arithmetic groups to contain more severely disabled children.

Verbal IQ.

The single case of Meningocele in the lowest arithmetic group is very severely retarded and cannot be regarded as typical of the condition. Apart from this there is a great consistency of Verbal IQ mean scores within each arithmetic group, irrespective of the diagnosis. The only significant differences occur in Group 2 between both Myelomeningocele groups and the Meningoceles(P=0.01). However since there are only two children in the Meningocele group little weight can be attached to this finding. There are no significant differences between the shunted and non-shunted Myelomeningoceles or between the Myelomeningoceles and Meningoceles in Groups 3 and 4.

There is, as was shown by the high F-ratio in the first analysis(P=0.0001), a considerable difference between the arithmetic groups in terms of Verbal IQ.

The figures given in Table 13 would suggest that the presence of a shunt does not have a significant effect on Verbal IQ and that children with Meningocele are not significantly superior to those with Myelomeningocele, within the same range of arithmetical ability.

Performance IQ.

There is much more variability within the arithmetic groups between the different diagnoses. This is in addition to the highly significant difference between the groups, as shown in the first analysis. In the top two arithmetic groups the Meningoceles and the non-shunted Myelomeningoceles are at a similar level but there are significant differences between the shunted and non-shunted Myelomeningoceles in all but the bottom group, as follows:-

Group 2 - t = 2.75
Group 3 - t = 5.62
Group 4 - t = 2.76 P =<0.01 in all groups.

These findings would suggest that the presence of a shunt has an effect on Performance IQ which it does not have on Verbal IQ. However it may not be the presence of the shunt but the presence of the Hydrocephalus which is the crucial factor. Group 2 was the only one where there was a significant difference between the Meningoceles and the non-shunted Myelomeningoceles . Since the former group contained only two children this finding must be viewed with caution.

Full Scale IQ.

Only Groups 2 and 3 showed a significant difference between the mean IQ scores of the shunted and non-shunted Myelomeningoceles at P=0.05 and P=0.01 respectively.
The greatest influence on these differences in Full Scale IQ comes from the scores on the performance scale. The presence of Hydrocephalus(as indicated by shunt treatment) would seem to be a major factor influencing the Full Scale IQ by virtue of having a more severe effect upon the performance than the verbal scale.

Table 15. Full Scale IQ for the three diagnoses, subdivided into arithmetic ability groups.

	Myelomeningocele with shunts			Myelomeningocele without shunts			Meningocele		
	M	SD	N	M	SD	N	M	SD	N
Group 1	61.9	12.6	64	67.7	10.3	11	40.0	0	1
Group 2	76.4	10.8	123	80.8	11.2	58	90.0	1.4	2
Group 3	89.7	12.4	147	97.3	12.2	89	96.4	13.5	27
Group 4	106.2	10.0	28	112.6	13.5	28	112.6	10.1	13

The largest discrepancies between Verbal and Performance IQs occur in the shunted groups as follows:-

Table 16. Differences in verbal and performance mean scores.

	Group 1	Group 2	Group 3	Group 4
Myelomeningocele with shunt	11.3	10.0	18	27.2
P	NS	NS	0.01	0.01
Myelomeningocele without shunt	5.3	6.2	12.8	18.4
P	NS	NS	0.05	0.01
Meningocele	0	6.0	8.6	18.3
P	NS	NS	NS	0.01

Significance worked out from Sattler(1982).

Dennis(1981) suggested that the verbal and performance scores were most similar when the overall IQ was around 100. Thus Group 3 would not be expected to show the high discrepancies which occur in both of the Myelomeningocele groups, with the shunted group being the highest. Although some discrepancy might be expected in Group 4 that shown is high and is significant at the P=0.01 level in all the diagnoses.

Freedom from Distractibility Quotient(Sattler 1982).

Sattler(1982) in a discussion of factor analysis of the WISC suggests that the sub-tests fall into three clusters, which can be used to work out three quotients, instead of the usual two. These are:-

a) Verbal comprehension; which measures verbal knowledge and comprehension, the knowledge being partly a product of formal education. This is calculated from the scores of information, similarities, vocabulary and comprehension scales.

Table 17. Verbal Comprehension, Perceptual Organisation and Freedom from Distractibility mean Quotients.

Myelomeningocele with shunt

Arithmetic group	1	2	3	4
N	64	125	147	28
Verbal Comprehension	74	85	99	115
Verbal IQ	71	83	99	118
Perceptual Organisation	62	76	82	92
Performance IQ	59	73	81	91
Freedom from Distractibility	58	74	87	107
Full Scale IQ	62	76	89	106

Myelomeningocele without shunt

Arithmetic group	1	2	3	4
N	12	58	89	28
Verbal Comprehension	76	87	103	116
Verbal IQ	72	85	104	120
Perceptual Organisation	71	81	90	100
Performance IQ	67	79	91	102
Freedom from Distractibility	65	78	93	111
Full Scale IQ	67	81	97	112

Meningocele

Arithmetic group	1	2	3	4
N	1	2	27	13
Verbal Comprehension	47	99	100	118
Verbal IQ	45	93	101	120
Perceptual Organisation	42	94	94	103
Performance IQ	45	87	92	102
Freedom from Distractibility	41	78	93	113
Full Scale IQ	40	90	96	112

Calculated from scale scores on the WISC(Sattler 1982). Verbal, Performance and Full Scale Quotients given for comparison.

b) Perceptual organisation; which is a non-verbal factor reflecting the ability to interpret and organise visually perceived material. This is calculated from the scores of picture arrangement, picture completion, block design and object assembly scales.
c) Freedom from Distractibility; which measures the ability to maintain attention and concentration and relates to numerical skills. This is calculated from the scores of arithmetic, digit span and coding scales.

These quotients were calculated from the data in this study using tables from Sattler(1982). It was felt that the Freedom from Distractibility Quotient in particular, might have relevance to a study of maths problems, especially if there was a significant difference between it and the other quotients. Tew(1983) had found that teacher's estimates of concentration span in children with Spina Bifida and Hydrocephalus correlated highly with results in mathematics. Tew and Laurence(1980) also found that deficits of attention were one of the main problems shown in school by these children.
The mean quotients are shown in Table 17 with the Verbal, Performance and Full Scale IQs given for comparison.

The following significant differences between quotients were shown:-

The group of Myelomeningoceles with shunts.

P= 0.05

Verbal comprehension and Perceptual organisation - Group 1.
Perceptual organisation and Freedom from distractibility - Group 4.
Verbal comprehension and Freedom from distractibility - Group 1.

P= 0.01

Verbal comprehension and Perceptual organisation - Groups 3/4.

The group of unshunted Myelomeningoceles.

P= 0.05

Verbal comprehension and perceptual organisation - Group 3.

P= 0.01

Verbal comprehension and Perceptual organisation - Group 4.

<u>The group of Meningoceles.</u>

<u>P= 0.05</u>

Verbal Comprehension and Perceptual Organisation - Group 4.

Perceptual Organisation and Freedom from Distractibility - Group 2.

<u>P= 0.01</u>

Verbal Comprehension and Freedom from Distractibility - Group 2

It has already been stated that the presence of a shunt with Myelomeningocele shows a significant effect on performance IQ. This can help to explain the difference between the non-shunted and shunted Myelomeningoceles within each arithmetic group. However this is not enough to explain why some children with shunts are able to perform well enough on the arithmetic sub-scale of the WISC to fall into Group 4, i.e. to score 13 or more, despite the comparative deficit on the performance scale. The Freedom from Distractibility Quotient suggested by Sattler(1982) may help in this explanation.

This quotient for the shunted children in Group 4 is 107 which is significantly different(P=0.05) from the Perceptual Organisation Quotient, the latter being only one point different to the Performance IQ. The Freedom from Distractibility Quotient is based on two sub-scales from the verbal scale and one from the performance scale of the WISC. Possibly the items involved in this quotient play a more important part in the development of arithmetic skills than do the items involved in Perceptual Organisation. For all sub-groups but one the Freedom from Distractibility Quotient is within five points of the Full Scale IQ. The one exception is interesting despite the fact that it is for a very small sample of only two Meningoceles in the second arithmetic group. It may help to explain why, when both verbal and performance IQs fall into the normal range (at 99 and 87 respectively), these children are in an arithmetic group lower than one Standard Deviation below the mean(scores 5-7). When the Freedom from Distractibility Quotient is calculated it is only 78 but extracting these scores leaves a Verbal Comprehension Quotient of 99 and a Perceptual Organisation Quotient of 94, suggesting that neither of these areas of ability are lacking. Tew and Laurence(1972) warn that taking the IQ scores of these children at face value may mask subtle learning problems. Possibly this is what is reflected here.

Although these are only tentative explanations it is likely that distractibility plays an important part in the poor development of mathematical skills in these children.

In children who are distractible their surroundings will play a very important part in their ability to learn, especially in a sequential subject like maths. In this respect placement in a school for physically handicapped children, where there tends to be a lot of movement in and out of class for medical treatment, may cause extra difficulty. Carr et al.(1981) found that Spina Bifida children in mainstream school performed better in maths than those in special school, despite being matched for intelligence. Whilst recognising that the children in the special school tended to be more severely physically handicapped they also suggested that the type of school could have an effect. The level of distraction is possibly one of the things to consider in this respect.

Table 18.

Variables which correlate highly with arithmetic ability (0.001 level) and a comparison with similar variables and their correlation with reading.

The variables are placed in descending order according to their correlation with arithmetic.

	Arithmetic	Reading
Verbal I Q	0.79(N 604)	0.66(N 540)
Full I Q	0.78(N 602)	0.67(N 604)
W I S C Information	0.67(N 604)	0.64(N 527)
W I S C Vocabulary	0.62(N 593)	0.56(N 520)
Performance I Q	0.61(N 602)	0.54(N 540)
Reading	0.60(N 526)	
W I S C Block design	0.59(N 599)	0.46(N 524)
W I S C Similarities	0.58(N 600)	0.50(N 525)
W I S C Coding	0.56(N 579)	0.50(N 507)
W I S C Picture arr.	0.53(N 568)	0.48(N 508)
W I S C Comprehension	0.51(N 593)	0.50(N 521)
W I S C Picture comp.	0.49(N 602)	0.42(N 527)
Present school	-0.49(N 598)	-0.47(N 606)
W I S C Digit span	0.44(N 546)	0.52(N 481)
W I S C Object ass.	0.37(N 576)	0.29(N 518)
Locomotion method	-0.29(N 603)	-0.19(N 606)
Year of birth	0.24(N 604)	0.16(N 607)
Shunt	-0.21(N 598)	-0.18(N 603)
Age in years	-0.21(N 604)	-0.14(N 607)
Social class	-0.20(N 528)	-0.20(N 527)
Neonatal pallium	0.19(N 388)	0.13(N 393) .005
Continence	-0.18(N 589)	-0.06(N 587) N.S.
Number of live sibs.	-0.16(N 598)	-0.22(N 600)
Diagnosis	-0.15(N 604)	-0.11(N 607) .003
Location	0.15(N 583)	0.12(N 587) .002

Reading Quotient

Arithmetic and reading were found to be correlated significantly with 'r' being -0.60(P=0.001) and an F-ratio of 89.2(P=0.0001). 528 children were involved.
In a large sample such as this it is likely that the effect of intelligence will be reflected in both arithmetic and reading scores. In a comparison of variables which correlated highly with arithmetic it was found that similar results were obtained for reading. These are shown in Table 18 and it can be seen that the correlations are slightly lower. Noticeable differences occur with diagnosis, location, thickness of neonatal pallium and continence, all of which are less significant in reading than arithmetic. This would suggest that severity of handicap has a greater effect on ability in arithmetic than in reading, in the same way that it has a greater effect on performance than verbal IQ. This may link up with the restricted opportunities for movement and interaction in early life in those children who are more severely handicapped, whereas the incidental early reading experiences can still take place. Tew and Laurence(1976) make this point in a study of the effects of hospitalisation on the abilities of young Spina Bifida children.
Of the variables which were not significant at the 0.001 level it is worth commenting on that of ventricle-brain ratio which was only available for 207 children. When correlated with arithmetic it was significant at the 0.004 level but was not significant when correlated with reading. Factors which might have been expected to correlate significantly with arithmetic and reading but did not at the level being considered were head circumference at birth and the extent of the lesion, both of which are related to the severity of the condition.
No significant differences were found between male and female subjects as might be expected in the normal school populations(Walkerdine and Walden 1981).

Second analysis.

The first analysis had shown that there was a high correlation between reading quotient and arithmetical ability and in this second analysis the differences within the arithmetic groups were mostly insignificant. The only significant differences were found in Group 2 between both of the Myelomeningocele samples and the Meningoceles, with 't' being 3.01 and 2.71 respectively. In both cases significance was at the 0.01 level. It must be remembered that this Meningocele sample contained only two children. It was between exactly the same sub-groups that there were significant differences in Verbal IQ which is not surprising as in the first analysis reading was found to correlate at the 0.001 level with Verbal IQ. These findings support those in the first analysis which suggest that severity of handicap does not have as significant an effect on reading ability as on ability in arithmetic.

Present school.

Ability in arithmetic and type of school attended correlate significantly ,with 'r' being -0.45 which is significant at the 0.001 level. This is supported by an F-ratio of 51.3(P=0.0001). This indicates that the difference between the four arithmetic groups in terms of the type of school attended is considerably greater than the difference within the groups.

As might be expected there is a clear gradation through the groups with the poorest group for arithmetic containing many more children who are in schools for the physically handicapped or in other special schools. 85-90% of the bottom group fall into this category through to only 28% in the top group. This would suggest that the children who are better at arithmetic are easier to integrate into normal schools, not because of this ability but because it also links with general intelligence and the severity of the handicap. It would seem likely that the children are in normal school because they are less physically handicapped and more intellectually able, rather than that the children in normal school are better at arithmetic because they are in such schools. Halliwell et al.(1980) found that children with Spina Bifida who attended normal school performed better in basic subjects, particularly maths, than children who attended schools for physically handicapped children, even though they were matched for IQ. They made the comment that it was likely that the children remaining in schools for the physically handicapped were those whose handicap was more severe. As already mentioned Lonton(1981) had found that low intelligence and wheelchair dependency were the two factors that militated most against integration.

Second analysis.

In the bottom two arithmetic groups there are no significant differences in school placement between the three sub-groups based on diagnosis. However in Group 3 the difference between the Myelomeningoceles with and without shunts is significant ('t'=3.97 P=<0.01) as is the difference between both these groups and the Meningoceles ('t'=6.11 and 11.65 respectively.P=<0.01). Despite the fact that they all score within the range of the same arithmetic group there is still a greater likelihood of the children with Myelomeningocele, particularly those with shunts, being in a special school, whereas those with Meningocele tend to be in normal schools. It is likely that this is related to degree of physical disability.

In Group 4 the difference between the children with Myelomeningocele with and without shunts is significant at the 0.05 level as is that between the shunted children and the Meningoceles. However the difference between the Myelomeningoceles without shunts and the Meningoceles is not significant. Even in this top group where their arithmetic scores are greater than 13 the shunted Myelomeningoceles have a greater likelihood of attending special schools or units than the other two groups. The fact that this situation arises does not really support the suggestion of Carr et al.(1981) that children in normal school perform better at maths than those in special school due to the better quality of the teaching in the former. Rather it supports the view that placement is determined very much by degree of disability and that within special schools some children can perform well. The more severely disabled children have a tendency to be the less intellectually able and are more likely to be placed in special schools.

Indications of physical handicap.

Diagnosis.

The data shows a trend for a higher percentage of children with Myelomeningocele to be in those groups with poor results for arithmetic. The top arithmetic group has a greater percentage of children with Meningocele. With 600 children included in this part of the analysis 'r' was 0.15, significant at the 0.001 level and 'F' was 6.5 which was significant at the same level.

Second analysis.

The second analysis gave the breakdown of the distribution of Myelomeningoceles and Meningoceles in each arithmetic group. This is shown in Table 26 which has already been discussed. There were only 43 Meningoceles included in this study. In this analysis ,which did not include other neural tube defects,the difference between the arithmetic groups in terms of diagnosis became even more highly significant, with 'F' = 11.16 and P =<0.0001. This gives a clear indication that the type of lesion is an important variable in the consideration of ability in arithmetic. The view has already been expressed that this is an area which is greatly affected by the severity of the physical handicap and other indications of this will now be considered.

Location and extent of the lesion.

These variables were of less significance than diagnosis in relation to arithmetic results.

Location - 'F' = 3.0(P=0.05) ; 'r' = 0.15(P=0.001); N =583.

Extent - 'F' , Not Significant; 'r' = -0.15(P=0.05);N=126.

There was a general trend through the groups to there being more higher lesions among the children with poorer arithmetic scores. There was also a slight general trend to there being more vertebrae involved in the poorer children. However the part of the analysis concerned with the extent of the lesion only contained 126 children.

Second analysis.

Location. Within the arithmetic groups there are several significant differences between the sub-groups based on diagnosis. In all four arithmetic groups there is a significant difference between the shunted and non-shunted Myelomeningoceles with P= 0.01 in Groups 1 - 3 and 0.05 in

Group 4. This would seem to reflect the fact that Hydrocephalus occurs more frequently in higher lesions(Milhorat 1972).

Extent. The second analysis showed significant differences occurring between all three sub-groups in arithmetic group three.

Myelomeningoceles with and without shunts; 't' = 2.01
P = 0.05

Myelomeningoceles with shunts and Meningoceles;'t' = 3.75
P = 0.01

Non-shunted Myelomeningoceles and Meningoceles;'t' = 2.02
P = 0.05.

There was also a significant difference at the 0.05 level between the shunted and non-shunted Myelomeningoceles in Group 1. There is a tendency towards more extensive lesions in those children with Myelomeningocele, particularly those with shunts.

As shown by the first analysis the extent of the lesion was not significant when related to placement in the arithmetic ability groups and the location of the lesion was only significant at the 0.05 level.

Thus diagnosis is of far greater relevance than either the extent or the location of the lesion, although higher lesions are likely to be more severe and to be associated with Hydrocephalus.

Continence.

This is linked to the physical condition of the child but it must be remembered that those with sacral lesions are likely to be incontinent and this may be the only physical problem they have. Both 'F' at 6.4 and 'r' at -0.18 are significant at the P=0.001 level in this group of 589 children.

The poorest arithmetic group contained 82% of incontinent children compared with 64% in the top group. There is a definite dividing line between the best two groups and the other two groups. Group 2, which contained on average the oldest children, also had the highest percentage of children with Myelomeningocele and the highest percentage of incontinent children.

The second analysis did not provide any additional information.

Locomotion.

This was the most significant of the variables indicating physical condition, in relation to arithmetic scores. 'F' at 15.5 was significant at the 0.0001 level and 'r' at -0.29 was significant at the 0.001 level. 603 children were included. The poorest of the arithmetic groups contained many more wheelchair bound children than the best group and the trend through the other groups was similar. Again there was a clear division between the two best and the two poorest groups.

The data showed a definite tendency for the least mobile children to be the least able at arithmetic.

Second analysis.

However within the arithmetic groups there are significant differences between the shunted and non-shunted Myelomeningoceles in all but the poorest group, and between the Myelomeningoceles and Meningoceles in Groups 3 and 4. The significance of these differences is shown here:-

		't'	P
Myelomeningocele with and without shunts.			
	Group 2.	3.00	0.01
	Group 3.	6.60	0.01
	Group 4.	3.42	0.01
Non-shunted Myelomeningocele /Meningocele.			
	Group 3.	5.89	0.01
	Group 4.	3.33	0.01

Although the within group differences are outweighed by the between group differences there is a tendency for the children with Myelomeningocele and shunts to be more physically handicapped than the other two sub-groups, even within the top arithmetic group. This is reflected in school placement which has already been mentioned.

Head circumference at birth.

This does not show up as being significant although there is a difference in means among the groups, ranging from 352mms. to 346.3mms. Lonton(1982) suggested that it is only at the extremes that this factor would be significant, i.e. above 390mms. or below 310mms.

Second analysis.

None of the sub-groups based on diagnosis falls into the category that Lonton(1982) considers at risk but there are significant differences between some of the sub-groups. The difference between the shunted and non-shunted Myelomeningoceles is significant(P= 0.01) in the bottom three groups but not in the top one.

Group 1 - 't' = 3.60
Group 2 - 't' = 3.68
Group 3 - 't' = 5.55

There are no significant differences between the non-shunted Myelomeningoceles and the Meningoceles.
The means are of interest, with the shunted Myelomeningoceles showing a considerably larger head circumference at birth, as would be expected as this is one of the indices used to diagnose Hydrocephalus. Although the differences are not significant the means for those with Meningocele are higher than those for the non-shunted Myelomeningoceles.

Table 19. Mean Head Circumference at Birth.

Arithmetic Group	Myelomeningocele with shunts			Myelomeningocele without shunts			Meningocele		
	M	SD	N	M	SD	N	M	SD	N
Group 1	357.0	28.9	58	322.3	18.1	10	324.0	0	1
Group 2	353.0	21.1	104	340.3	17.6	41	342.3	3.5	2
Group 3	354.8	24.6	129	336.8	19.4	66	345.5	19.8	23
Group 4	349.5	16.3	21	339.9	16.7	21	346.6	23.1	11

Assuming that the head circumference at birth relates to the presence of Hydrocephalus it is worth considering the fact that within the Meningocele group which totalled 43 (although only 37 are included in this analysis),ten children had shunts. One shunted child was in Group 1, six in Group 3 and three in Group 4. This could be the reason for the somewhat larger mean for head circumference.

Presence of shunt.

Both 'F' at 9.1(P=0.0001) and 'r' at -0.2147(P=0.001) are significant. The range is from 87% to 46% which shows far more shunted children in the bottom arithmetic group. Lonton(1979) suggests that shunts are only associated with skill deficits when the ventricles are very large or very small(over or under drainage). There may in fact be an optimal size for ventricles.

Thickness of neonatal pallium.

For the 384 children included in this part of the study both 'F' (6.2) and 'r' (-0.29) were significant at the 0.001 level.

The trend appears to be that a thinner neonatal pallium is associated with a poorer level of ability at arithmetic. Lonton(1982) suggests 20mms. of pallium as being a guide as to whether the intellectual level of the child will be adversely affected. The bottom group here has a mean pallium thickness of only 18.8mms. with the second group falling only just above the 20mms. Lonton also comments that this is not always a good indicator of ability as will be discussed in the consideration of ventricle-brain ratios. He suggests that a relatively slow brain insult occurring in infancy or before birth, coupled with a presumed massive overprovision of relatively plastic brain cells(Lorber 1980) may not necessarily lead to intellectual loss. Such problems are likely to be caused by sudden brain trauma at any time or slow deterioration after this relatively plastic stage.

Second analysis.

Within the four arithmetic groups there are some significant differences between the sub-groups based on diagnosis.

In all arithmetic groups there is a significantly thicker cortex in those non-shunted Myelomeningoceles than those with shunts(P= 0.01). There are no significant differences between the Myelomeningoceles without shunts and the Meningoceles.

In the shunted Myelomeningocele group the thickness of the pallium increases very little through the top three arithmetic groups. This finding is not surprising in the light of previous research(Lorber 1981, Lonton 1979).

As the measurement of the thickness of the pallium is taken near the time of birth it does not give any indication as to what extent the cerebral cortex can develop once shunting has taken place. Neither does it give any idea of the thickness of different areas of the pallium. Young et al.(1973) suggests that it is the thickness of the frontal cerebral cortex that relates to the development of IQ and McNab(1965) states that it is the frontal and occipital lobes that will be most stretched in Hydrocephalus.

Table 20. Mean thickness of neonatal pallium(mms.).

Arithmetic Group	Myelomeningocele with shunts			Myelomeningocele without shunts			Meningocele		
	M	SD	N	M	SD	N	M	SD	N
Group 1	18.0	6.9	53	24.2	2.9	6	25.0	.0	1
Group 2	19.2	5.5	90	25.8	6.3	25	24.0	1.4	2
Group 3	19.8	5.6	117	26.1	6.4	50	28.5	6.0	9
Group 4	20.2	3.9	18	28.8	6.5	16	25.0	4.8	4

CAT scan - Ventricle-brain ratio.

The F-ratio relating this measure to ability in arithmetic was only 3.3 which was significant at the 0.02 level. Although this does not have as high a level of significance as many of the other variables it must be remembered that only 207 cases were included thus making it of more significance than it at first appears. Likewise with the correlation coefficient of -0.19(P=0.004). The data suggests a clear indication that loss of brain tissue results in lower scores but this is by no means always the case. Lorber(1980) asked the question "Are brains necessary", having studied a young man who had a 95% ventricle-brain ratio and a first class honours degree in maths. This means that 95% of the brain was occupied by the ventricles so the person concerned had virtually no cerebral cortex. He showed a verbal/performance discrepancy of 47 points on the WAIS. However Jackson and Lorber(1984) comment on the difficulty of estimating the actual quantity of cortex that exists and state that it is easy to assume that individuals with a very thin cerebral mantle have far less brain substance than actually exists. They further suggest that in those with a large head it is probable that although the cortex is thinned out its total volume may not be as severely reduced as it appears on the CT-scans which they studied. They therefore used the maximal head circumference, taken at the time of the scan, as an additional measure from which to calculate brain mass. They emphasise that at this stage their findings are tentative but in the light of this recent research it can be seen that the findings of any earlier research using estimates of brain mass (Tromp 1979) must be viewed with caution. However until any of these methods are proven, which at present can only be done by necropsy, previous findings may be used as a guide.

The measurements in this study were obtained by the same methods as those used by Lonton(1979).

In this sample the poorest arithmetic group has a VBR of 44.2% and the best 27.4% which is a considerable difference. Lonton(1979) suggests that VBRs of 10-20% are likely to be the normal range for the non-handicapped population but dangers from radiation in this type of examination make this suggestion difficult to substantiate.

Second analysis.

The CT-scan % ventricle/brain ratio data for the split groups provides some interesting findings but it does not give any definitive answers. The first analysis showed a definate trend towards a smaller percentage of ventricle related to brain area throughout the arithmetic groups moving from bottom to top. Using the 't' test of the significance of the difference between means the only significant differences within the groups occurred in Groups 3 and 4 as follows:-

Group 3

Myelomeningoceles with and without shunts - 't'=3.96; $P=<\cdot 001$.

Myelomeningoceles without shunts and Meningoceles - 't'=3.92 $P=<\cdot 001$.

Group 4

Shunted Myelomeningoceles and Meningoceles- 't'=5.30; $P=<\cdot 001$.

Group 4 (cont).

Myelomeningoceles without shunts and Meningoceles- 't' = 6.73
P = <.001.

In Groups 2 -4 the Myelomeningoceles with shunts have smaller ventricles than those without, although it is only in Group 3 that the difference is significant. This is presumably as a result of being shunted. These figures could suggest that the non-shunted group also contains children with Hydrocephalus since the percentage of ventricles is considerably higher than the 10-20% suggested by Lonton(1979) as being normal, although as has already been mentioned, he did point out that there was no information at the time on this subject. However Synek and Reuben(1976) had suggested that the normal ventricle was only 5% of the brain volume.

Table 21. Mean % Ventricle/brain ratios.

Arithmetic Group	Myelomeningocele with shunts			Myelomeningocele without shunts			Meningocele		
	M	SD	N	M	SD	N	M	SD	N
Group 1	40.8	11.5	9	34.6	12.5	5	0	0	0
Group 2	32.6	25.3	18	34.4	11.8	39	38.0	17.0	2
Group 3	23.7	14.1	37	36.2	15.5	53	16.1	13.1	8
Group 4	25.7	15.3	15	32.5	15.8	15	4.0	2.0	3

The large standard deviations shown in this table suggest that there is a considerable range of ventricle sizes within each subgroup. Group 4 is of particular interest as these are all children who scored above 13 on the WISC arithmetic sub-scale. These results show that children with a very wide range of ventricle sizes can perform well, with ventricles well below and well above what Lonton(1979) suggested as normal. He suggested that shunt-treated Hydrocephalic children with very small ventricles could also be at risk educationally because they are frequently those in whom overdrainage has occurred(Gruber 1982). It may well be that the same problems do not occur when small ventricles occur naturally.

The total number of children included in this part of the analysis was only 204 of which only 13 were meningoceles. As the Meningocele group was so small it was not realistic to make generalisations about them.

The discussion of the measures relating to Hydrocephalus; i.e. ventricle size, head circumference and thickness of neonatal pallium, illustrates that although there may be a trend to better performances among those with these measures in a certain range, there is no certainty about it. There is still a lot which is not known about what is 'normal' for the brain, and how it functions, as was mentioned in Chapter 2.

Treatment with Isosorbide.

The data on the use of isosorbide does not give any significant results but the number of children involved in this part of the analysis was only 60. However a greater number of these children fell into the top two arithmetic groups with the distribution being as follows:-

Table 22. The distribution of children treated with Isosorbide.

Arithmetic Group	Total treated with isosorbide	Shunted	Shunted children as % of total.
1	5	4	80%
2	14	13	92.9%
3	30	20	66.7%
4	11	5	45.5%
Totals	60	42	70%

Tew(1983) in his consideration of the differences in findings between research carried out in South Wales and Sheffield, particularly in relation to the discrepancy betwen verbal and performance scores, suggests that the use of isosorbide in Sheffield may have delayed or avoided surgery. He goes on to say that although this diminishes ventricular expansion, surgery gives rapid relief from the Hydrocephalus and allows restoration of the cerebral mantle to take place. This perhaps results in higher performance scores and overall intelligence. A study of the data from Sheffield does not support these views.

The number of children treated with isosorbide is in fact very small in comparison to the total sample of 594 cases. Lorber(1972) found in a clinical trial at Sheffield that the proportion of children avoiding surgery could be increased and operations carried out later where needed. Of the 60 children considered here only 18 avoided surgery altogether and Tew(1983) and Soare and Raimondi(1977) would favour the other 42 having surgical treatment for the Hydrocephalus earlier. Tromp(1984), however, found that the timing of surgery had no bearing on the development of IQ. The IQ scores for this group of children are shown in Table 23 with the mean IQs for the total group given for comparison.

Table 23. Comparative IQs of the total sample and those treated with isosorbide.

	Full scale		Verbal		Performance	
	All	Iso.	All	Iso.	All	Iso.
Myelomeningocele with shunts	81.5	87.1	90.0	94.9	75.3	80.8
N	364	40				
Myelomeningocele without shunts	92.7	95.8	98.3	105.2	87.4	85.7
N	187	18				
Meningocele	99.7	85.0	105.1	95.0	93.9	76.0
N	43	2				
Total	86.4	89.7	93.8	97.9	80.5	82.1
N	594	60				

It can be seen that the group treated with isosorbide have higher mean scores than the complete group and it must be remembered that it is likely that the children considered for this treatment are the milder cases for whom the prognosis was good.

It would appear from the data that in the shunted group the delay in shunting whilst the child was undergoing isosorbide treatment has not had a deleterious effect. They have mean scores between four and six points higher than the total sample on all the IQ scales, with the verbal/ performance discrepancy being slightly lower than in the whole group.

In the non-shunted Myelomeningoceles treated with isosorbide the Verbal and Full-scale IQs are slightly higher than for the whole group of non-shunted children, many of whom must be assumed to have no Hydrocephalus. Hydrocephalus must be assumed in the children treated with isosorbide and medical opinion must have been that this had been satisfactorily arrested by this treatment. The verbal/performance discrepancy for this group is considerably higher than that for the total group . The poorer relative performance IQ of this group would suggest that it is a concomitant of Hydrocephalus, however treated. Also those requiring shunts following isosorbide treatment have lower IQs generally. The two isosorbide-treated Meningoceles both required shunting and their scores are very similar to the shunt-treated Myelomeningocele group.

Table 24. Verbal/Performance discrepancies.

		Total group	Isosorbide treated
Myelomeningocele with shunts		14.7	14.1
	N	364	40
Myelomeningocele without shunts		10.9	19.5
	N	187	18
Meningocele		11.2	19.0
	N	43	2
Total		13.3	15.8
	N	594	60

As the largest group of children treated with isosorbide is that of the shunt treated Myelomeningoceles(N=40) and their verbal/performance discrepancy is lower than that of the group as a whole this does not support Tew's(1983) suggestion that it is this form of treatment which leads to the large differences between the mean verbal and performance scores in the Sheffield data. This difference is undoubtably present anyway and the explanation of it relating to the type of population studied is far more likely. Searching through the input data for the computer analysis revealed that many Meningoceles were not included in the maths analysis because full testing had not been carried out. This is because they were the milder cases who were discharged from hospital in their early years. Thus only a total of 43 out of 207 Meningoceles were included in the present analysis. Likewise data was missing for 446 of the 997 cases of Myelomeningocele partly for the same reason. Other factors also played a part with some children having been tested on scales that did not include arithmetic, either because they were tested before the WISC/WPPSI was the most common instrument used, or because they were so young or so retarded that developmental scales were used. These figures would support Tew's suggestion about the type of population studied. In South Wales the study was community based and therefore included mild cases whereas the Sheffield data was hospital based and therefore only included those children who needed to return to hospital for follow up. There seems little doubt that very many milder cases are not included in the Sheffield data, which leaves children in the study who are more severely disabled and as has already been mentioned have lower performance IQs. Isosorbide may, as Lorber(1972) and Haydn and Shurtleff (1972) suggest, have temporary favourable clinical effects which outweigh any damage caused by delays in shunt treatment.

CHAPTER SEVEN - Part 3.

Analysis for children with Congenital Hydrocephalus.

Summary of the research findings.

Congenital Hydrocephalus.

In the children with Spina Bifida the presence of Hydrocephalus appeared to be a major factor contributing to poor performance IQ and poor maths skills. It was impossible to separate the effects of Hydrocephalus from those of severe disability generally. For this reason the results of children diagnosed as having Primary Congenital Hydrocephalus were analysed in order to try to establish whether this was really a major factor on its own. Welch(1980/82) considered the possibility that in a study of Congenital Hydrocephalics some children who had suffered trauma at birth would be included in error. In a review of 100 cases of apparent Congenital Hydrocephalus he found only one which could be ascribed to subarachnoid haemmorrhage due to trauma at birth and concluded that this is an infrequent precursor of progressive Hydrocephalus. He suggests that a diagnosis of Congenital Hydrocephalus can be made with a high degree of accuracy. The children who were included in this part of the study all had such a diagnosis but not all clinicians would necessarily agree with this.
This Hydrocephalic group was separated into those with and without shunts on the computer analysis, but there were in fact few without shunts. When 't' tests were carried out there were no significant differences between the mean IQs of the shunted and non-shunted children so they were therefore considered as a total group. This would support the view that it is the presence of Hydrocephalus which is the deciding factor, even if it is not shunted. Some of those already quoted, such as Soare and Raimondi(1977) would not accept a diagnosis of arrested Hydrocephalus, but would shunt all the children.
When the mean IQs of those with Congenital Hydrocephalus were compared to those of the shunted Myelomeningoceles there were few significant differences, suggesting that there is considerable similarity between the two groups. Significant differences occurred in arithmetic Group 1 for both Verbal and Full-scale IQ and in Group 3 for Performance IQ. The children with Congenital Hydrocephalus who fall into the poorest arithmetic group are of very low overall intelligence, even compared to the shunted Myelomeningoceles.

Table 25. Comparison of IQ Means for the Congenital Hydrocephalic and Spina Bifida samples, in arithmetic sub-groups.

a) Verbal IQ.

	Group 1.			Group 2.		
	M	SD	N	M	SD	N
Congenital Hydrocephalus	60.8	9.4	29	84.2	11.7	28
Myelomeningocele with shunt	70.6	12.9	64	83.0	11.2	125
Myelomeningocele without shunt	72.4	9.6	12	85.2	10.2	58
Meningocele	45.0	0	1	93.5	2.1	2
All Spina Bifida	70.6	12.7	77	83.8	10.9	185

	Group 3.			Group 4.		
	M	SD	N	M	SD	N
Congenital Hydrocephalus	99.5	11.5	56	116.7	12.3	30
Myelomeningocele with shunt	99.1	12.8	147	118.4	13.2	28
Myelomeningocele without shunt	103.6	11.9	89	120.2	13.8	28
Meningocele	100.8	15.0	27	120.4	12.8	13
All Spina Bifida	100.8	12.9	263	119.5	13.2	69

Table 25. Comparison of IQ Means for the Congenital Hydrocephalic and Spina Bifida samples, in arithmetic sub-groups.

b) Performance IQ.

	Group 1.			Group 2.		
	M	SD	N	M	SD	N
Congenital Hydrocephalus	54.4	14.4	28	74.0	15.6	27
Myelomeningocele with shunt	59.3	12.5	64	73.1	12.5	123
Myelomeningocele without shunt	67.2	13.8	11	79.0	14.1	58
Meningocele	45.0	0	1	87.5	2.1	2
All Spina Bifida	60.3	12.9	76	75.1	13.3	183

	Group 3.			Group 4.		
	M	SD	N	M	SD	N
Congenital Hydrocephalus	87.5	13.5	56	91.6	20.4	30
Myelomeningocele with shunt	81.2	12.3	147	91.1	15.0	28
Myelomeningocele without shunt	90.8	13.1	89	101.8	14.0	28
Meningocele	92.2	11.6	27	102.1	11.5	13
All Spina Bifida	85.6	13.4	263	97.5	14.8	69

Table 25. Comparison of IQ Means for the Congenital Hydrocephalic and Spina Bifida samples, in arithmetic sub-groups.

c) Full-Scale IQ.

	Group 1.			Group 2.		
	M	SD	N	M	SD	N
Congenital Hydrocephalus	53.6	10.7	28	76.6	13.1	27
Myelomeningocele with shunt	62.0	12.6	64	76.4	10.8	123
Myelomeningocele without shunt	67.7	10.3	11	80.8	11.2	58
Meningocele	40.0	0	1	90.0	1.4	2
All Spina Bifida	62.5	12.6	76	77.9	11.1	183

	Group 3.			Group 4.		
	M	SD	N	M	SD	N
Congenital Hydrocephalus	93.4	11.7	56	105.3	15.2	30
Myelomeningocele with shunt	89.7	12.4	147	106.2	10.0	28
Myelomeningocele without shunt	97.3	12.2	89	112.6	13.5	28
Meningocele	96.4	13.5	27	112.6	10.1	13
All Spina Bifida	92.9	12.9	263	110.0	11.8	69

In Group 3 the fact has already been mentioned that the shunted Myelomeningocele sub-group still contains a number of children who are fairly severely handicapped and are wheel-chair bound and this may help to explain the difference between these children and the Hydrocephalics in Performance IQ. All of the Hydrocephalics in arithmetic Groups 3 and 4 are independently ambulant. The means for both groups are shown in Table 25.

The F-ratios relating the arithmetic group placement to a number of other variables are shown for both the total Spina Bifida group and the Congenital Hydrocephalics in Table 26.

Age at testing.

This variable was highly significant for the Spina Bifida group but was not significant for the Hydrocephalics. It is possible that this reflects the various treatment policies that have been in force for the children with Spina Bifida resulting in the younger children being a selected group who are more able both physically and intellectually.

Intelligence.

Both groups show that all the intelligence scales are highly significant in terms of performance in arithmetic.

Indications of physical disability and degree of Hydrocephalus.

The F-ratios for the indicators of physical disability vary between the two groups and this can give a guide as to the variables which cause the problems for the children with Spina Bifida. It suggests in fact that it is an interaction of variables rather than any one variable in particular.

If Hydrocephalus were the deciding factor then it might be expected that the variables directly related to this condition, such as the percentage ventricle/brain ratio, thickness of cortex and head circumference at birth, would have a similar level of significance in both groups. The comment has already been made that the presence of a shunt in the Congenital Hydrocephalics did not give significantly different results in that group.

In neither group was the head circumference at birth significant but the thickness of the neonatal pallium was highly significant in the Spina Bifida group($P=0.0002$) but not significant in the Hydrocephalic group.

Table 26. A Comparison of the Significance of the F-ratios for arithmetic with various other variables in the Spina Bifida and Congenital Hydrocephalic Groups.

Variable	Spina Bifida		Hydrocephalus	
Year of birth	F	P	F	P
Year of birth	11.05	<0.0001	4.73	0.004
Age at test	13.07	<0.0001	1.20	NS
Verbal IQ	260.82	<0.0001	133.21	<0.0001
Performance IQ	115.42	<0.0001	35.86	<0.0001
Full Scale IQ	237.23	<0.0001	95.91	<0.0001
Reading Quotient	95.14	<0.0001	30.16	<0.0001
Present school	57.43	<0.0001	29.96	<0.0001
Locomotion	20.18	<0.0001	5.65	0.001
Diagnosis	11.17	<0.0001	Not relevant	
Presence of shunt	10.13	<0.0001	0.23	NS
Neonatal pallium	6.77	0.0002	1.36	NS
Continence	5.37	0.001	1.46	NS

The percentage ventricle/brain ratio, head circumference at birth and isosorbide treatment were not significant in either group.

The group of children with Congenital Hydrocephalus, in whom the effects of ventricular dilatation might have been expected to show the greatest effects on performance in arithmetic, did not show significant differences between the arithmetic groups for the related variables. The fact that these measures may not give a very good indication of the amount of cortex present in these children, has already been mentioned(Jackson and Lorber 1984).
Locomotion as a variable had very high significance in the Spina Bifida group but was also highly significant in those with Congenital Hydrocephalus. In the Hydrocephalic group all the children in the top two arithmetic groups are

independently ambulant whereas the bottom two groups contain some children who need aids to locomotion. This could be interpreted as indicating that mobility must be considered and that Hydrocephalus per se cannot be used as an explanation for problems in mathematics. However it is really not possible to separate the variables in this way as the children in both Spina Bifida and Hydrocephalic groups who perform poorly in arithmetic are also those who are the most intellectually and physically handicapped. It seems likely that these factors are also reflected in their school placement which also showed up as a significant variable. Dennis(1981) states that Hydrocephalus may impair the motor skills necessary for non-verbal intelligence tasks by deforming the cerebellum and thus affecting gross motor function, by disturbing the kinaesthetic-proprioceptive basis of hand control and by causing stretching of the corpus callosum and thus affecting bimanual motor function. Although the variables cannot be completely separated it would seem likely that the degree of mobility which the children have had during their early years will have played a part in the development of mathematical skills.

Summary of the main points from the Sheffield research.

The findings from the large scale data would suggest that the skills involved in arithmetic are affected more than the skills involved in reading in cases of severe physical handicap. A similar situation arises with non-verbal compared to verbal skills. Lonton(1982) makes the point that although intellectual ability is frequently linked to physical handicap in these children, this is not always the case. The following variables which are indicative of degree of disability all correlated highly(P=0.001) with poor arithmetic scores on the WISC:-

Diagnosis of Myelomeningocele
Presence of shunt
Thoraco-lumbar location
Incontinence
Limited mobility
Thinner neonatal pallium

In addition it was found that the younger children were more likely to be in the top groups for arithmetic. It was felt that this was likely to be due to the effects of selection. There was also a high correlation between school placement and ability in arithmetic with the children who were in the lower groups being most likely to be in schools for physically handicapped children, as their degree of disability tended to be greater.
The same variables regarding degree of disability were found to correlate less highly with reading ability although most of them were still significant at the 0.001 level. However continence was found to be an insignificant variable in this connection and neonatal pallium(P=0.005), location of lesion(P=0.002) and diagnosis(P=0.003) were significant at slightly lower levels.
Consideration will now be given to the variables suggested by the school based research as being of importance.

1) Intellectual development.

As would be expected(Tew1983) IQ, as measured by the WISC, is very highly correlated with performance in arithmetic, with Full Scale, Verbal and Performance scores all correlating with it at the P=0.001 level. Verbal IQ was not significantly different in the three different diagnoses and was not greatly affected by the presence of a shunt. Performance IQ on the other hand was affected with significant differences between the shunted and non-shunted Myelomeningoceles, and the non-shunted group being similar to the Meningoceles. The presence of a shunt seemed to affect Performance IQ rather than Verbal IQ with the greatest discrepancy between the two scores arising in the shunted groups. Those with the highest overall scores had the greatest discrepancies

Verbal IQ and arithmetic were both highly negatively correlated with age, with younger children performing better, possibly as a result of selection. The same effect cannot be seen in Performance IQ.

Some shunted children with low Performance IQs fell into the top arithmetic group whereas two children with Meningocele who had both Verbal and Performance IQs in the normal range were in the second bottom group, performing at a lower level than would be expected. Although a sub-group of only two can provide very limited information Sattler's (1982) Freedom from Distractibility Quotient is considered in this respect, as well as for the other groups. The findings suggested the possibility that distractibility was a variable which could have a serious effect on the development of arithmetic skills. Tew et al(1980) found that inattention was a serious problem in children with Spina Bifida and Hydrocephalus and Tew(1983) reported that teacher's estimates of concentration span correlated highly with scores on standardised tests in mathematics.

2) Mobility and severity of physical handicap.

The more severely physically handicapped children tended to be in the lower groups for arithmetic and to have lower Performance IQs. Diagnosis was highly significantly related to arithmetic scores with those with shunted Myelomeningocele tending to be the poorest. The children in the lower arithmetic groups were also more likely to be wheelchair bound and to have higher lesions. However even within the top arithmetic groups those with shunted Myelomeningocele were more physically handicapped than those without shunts and the meningoceles. Incontinence also correlated highly with arithmetic.

3) Hydrocephalus and neurological damage.

A number of the variables which showed a significant($P=0.001$) correlation coefficient(r) with the arithmetic scores were related to the presence of Hydrocephalus. These were the presence of a shunt, thickness of neonatal pallium and ventricle/brain ratio. There was a trend to better performance with ventricles, pallium and head circumference within a certain range, but large Standard Deviations suggested that there was considerable variability even within the arithmetic ability groups.

Due to the difficulty of separating out the effects of severe physical disability and Hydrocephalus, data for a group of children with Congenital Hydrocephalus was also analysed. The mean IQs of the shunted Myelomeningoceles and the Congenital Hydrocephalics were very similar. Only in the second best arithmetic group was there a significant difference which may reflect the greater physical disability of the Myelomeningoceles in this group compared to the Hydrocephalics, all of whom were ambulant.

Locomotion was a highly significant variable related to the arithmetic groups in the Hydrocephalics. This may give some support to the view that the ability to move around in a normal fashion in early childhood is important, but it is linked with other variables connected with severe disability, which includes the degree of Hydrocephalus. This condition alone in its severe form can result in physical disability causing problems of mobility.

All the data supports the view that Hydrocephalus and its associated neurological damage is likely to be a major factor affecting the development of mathematical concepts in these children.

4) School placement.

This correlated highly with arithmetic scores. Those with low scores were more likely to be in special schools, probably due to their greater degree of physical disability and lower level of intelligence. Carr et al.(1981) found children matched for intelligence to be performing at a lower level in arithmetic in special schools, probably due to their greater degree of physical handicap. The distractions which tend to occur in such schools may also play a part in children who tend to be distractible anyway.

A Summary of the Research Findings in Relation to the Major Hypotheses.

A Summary of the Research Findings in Relation to the Major Hypotheses.

Hypothesis 1.

Many children with Spina Bifida and Hydrocephalus have difficulty in developing mathematical concepts.

The first section of the school based research confirmed the belief that children with Spina Bifida and Hydrocephalus have difficulty in developing mathematical concepts. The results of a total group of 68 children on the Young's Group Mathematics Test showed them to be poorer than both children with cerebral palsy and those with a wide range of other disabilities. They seemed to be able to cope with a certain degree of mechanical number skill but lacked an understanding of the concepts involved. The results shown by the children studied in detail also lent support to this hypothesis. By the age of 13 years six of the eight survivors,from the group of nine children studied, were performing at or above their chronological age in reading. However only three of them had reached the top of the scale for the mathematics test. This showed a large deficit in this area in many of the children.As the test had a top maths age of only 9.9years it would have been expected that most of the children would score at the top of the scale.

Hypothesis 2.

The problems shown by these children in developing mathematical concepts cannot be solely attributed to low general intelligence.

If low general intelligence were the only factor involved it might be expected that these children would have similar problems in maths and reading, but as mentioned above this is not so. Other researchers(Tew and Laurence1972, Tew 1983) have also found mathematics to be more retarded.

Although the large scale data gives slightly higher correlations for all IQ measures with arithmetic than with reading the evidence from the case studies and the large scale data also supports the view that there is a particular defect in the visuo-motor area of intelligence(Miller&Sethi1971)

In the case studies there was a tendency for the verbal aspects of intelligence to be at a higher level than the non-verbal. This was confirmed by the large scale data. Halliwell et al.(1980) and Tew(1983) did not find such discrepancies and the latter suggests that this could be due to the different types of sample. The Sheffield sample, which was hospital based, contained those children who had not been discharged in their early years, resulting in a more severely disabled sample than the others which were community based and included mild cases. However it also seems possible that the age of the sample affects the discrepancy. Spain(1974) had found large verbal/performance discrepancies in young children in the early part of the GLC study which contrasted with the later findings of Halliwell et al.(1980) in the same study.

In this research the younger children, who tended to be the most intellectually able showed the largest discrepancy. This may reflect 'selection' and the fact that the discrepancy is likely to be the greatest where the overall scores are highest(Dennis 1981). However it could also reflect the advanced verbal skills in the young child which drop back towards average as they get older(Parfitt and Green 1983). The case studies gave information which suggested that whereas the advanced early verbal skills cannot be maintained at that level the visuo-motor side of intelligence goes on improving slowly in these children , at least until the early teens. This suggests that development can go on at a later than normal age.

The misleading effect of the apparent intelligence of these children suggested by their verbosity may well affect the development of mathematical concepts in that formal maths is started too early and causes later problems. Parfitt(1979) found that the development of conservation was closely linked to the development of mathematical concepts and this view is supported by the case studies. He found that this developed at a later than normal age and it is possible that there is a link with the development of the visuo-motor side of intelligence.

Hypothesis 3.

Neurological damage associated with the presence of Hydrocephalus is a major cause of problems in developing mathematical concepts.

The results on the Young Group Mathematics Test in the school based research suggested that children who were neurologically damaged had more problems in mathematics than non-neurologically damaged children.

The large scale data supported this view with arithmetic correlating at the P=0.001 level with the presence of a shunt, thickness of neonatal pallium and ventricle/brain ratio. However although the results showed that generally better performances in mathematics could be expected from those whose brain and head measurements fell into a certain range, this was by no means clear cut. Possibly the variables which can be measured in the living subject are not the ones which give the most information about the degree of neurological damage. Jackson and Lorber(1984) suggest that findings from even the more sophisticated research, such as that using CT-scans, can be misleading. The effects of the stretching of the corpus callosum and the differential stretching of parts of the cortex, along with defects of myelination, are all areas which may be of importance.

When results from children with Congenital Hydrocephalus were studied the available variables indicative of the severity of Hydrocephalus were less significant in these children than in those with Spina Bifida. Degree of mobility was highly significant with respect to arithmetic scores in both groups, which suggests that other factors also play a part

However although the findings from this research do not indicate that Hydrocephalus is the only variable to affect ability in arithmetic it does appear to be a major one.

As the damage tends to be generalised stretching of the cortex it is not possible to localise its effect but any neurological damage is likely to have some similar sequelae. Strauss and Lehtinen(1947) point out that one of the concomitants of neurological damage is distractibility , which whey split into two aspects:-

a) Undue fixation of attention upon irrelevant external stimuli,

b) Fluctuation in the perception of object and ground.

The results from both the case studies and the large scale data suggest that visual-perceptual skills are poor in these children. Using the Frostig Developmental Test of Visual Perception in the case studies, the area of figure-ground perception showed up as exceptionally poor.
In the large scale data when Sattler's 'Freedom from Distractibility Quotient' was worked out the results suggested that it is not simply general intelligence per se, or even the non-verbal side as measured on the WISC, that affects the development of mathematics skills. Rather the possibility exists that the effects of distractibility play an important part in both measures.
Tew(1983) had demonstrated significant positive relationships between estimated concentration span and mathematical ability which was at a much higher level in the children with Myelomeningocele than in his control group.
Thus neurological damage would seem to be a very important factor in the development of mathematical concepts and it is possible that it is the distractibility caused by this which has the major effect. Other interacting variables are likely to affect the severity of the problem .

Hypothesis 4.

The degree of physical disability in children with Spina Bifida and Hydrocephalus is a major factor in the development of mathematical concepts.

In the case studies the children who were best at mathematics were less physically handicapped in terms of mobility. The large scale data also supported this hypothesis with the children who were better at maths tending to be less physically handicapped in terms of mobility and continence. However even within the more able group the shunted myelomeningoceles were more physically handicapped than the other children. The variables showing severity of handicap were more significantly related to scores in mathematics than reading.
In the children with Congenital Hydrocephalus locomotion was a significant variable in relation to their arithmetic ability group whereas variables indicative of severity of Hydrocephalus were not.

In Chapter 4 a lot of consideration was given to the importance of movement and interaction in early childhood for the development of perceptual and mathematical skills, and also in the development of selective attention.
This research suggests that those children who by virtue of their more severe disability have had less chance for movement in early life are likely to have more severe problems in the development of mathematical concepts. However this cannot be divorced from the fact that the children who are more severely disabled also tend to have a greater degree of Hydrocephalus and lower general intelligence.
It seems likely that lack of movement and interaction with the environment in early life adds to the problems that exist as a result of the neurological damage related to the Hydrocephalus.

Hypothesis 5.

The problems which children with Spina Bifida and Hydrocephalus have in developing mathematical concepts are caused by the interaction of a number of variables reflecting both their neurological status and their degree of physical disability.

It has already been mentioned that it is difficult to separate the effects of Hydrocephalus and physical handicap as the more severely physically handicapped children frequently have the greatest degree of Hydrocephalus. Even within the group with congenital Hydrocephalus the children in the bottom arithmetic group were more likely to need aids to mobility. Brocklehurst(1976) states that it is not only paralysis which hinders walking, as children with congenital Hydrocephalus often show delays in walking and difficulties in balance due to poor spatial orientation and cerebellar deficiencies. This may delay walking to beyond the age of four in children with seemingly normal musculature, which suggests that it is not actual physical handicap which is causing the lack of mobility in these cases.
This research has shown that the children who are in normal school tend to be those who are the least physically handicapped. They are also the most intellectually able, which once more indicates the inter-relatedness of several variables.

All of the hypotheses are supported by this research but it has also shown that several interacting variables affect the development of mathematical concepts in children with Spina Bifida. Thus Hypotheses 3 and 4 are absorbed by Hypothesis 5. Neurological damage and physical handicap are two of the main variables but these result in other variables having an effect. Such variables are school placement, hospitalisation and impoverished early childhood experiences.

The next chapter will consider possible ways of improving the performance of children with Spina Bifida in mathematics. To prove the efficiency of such ideas would require a full scale longitudinal study which was not feasible in the context of this research.

CHAPTER EIGHT.

Suggestions for improving the development of mathematical concepts in children with Spina Bifida.

The ideas suggested for teachers are based on work carried out with Spina Bifida children in a school for the physically handicapped and with children with motor development problems in another special school. To investigate the value of these suggestions fully would require a full-scale longitudinal study with a sample of suitable size. This was not possible in the context of this study, therefore the ideas are given because it was felt that they were proving beneficial with the small number of children involved.

Suggestions for improving the development of mathematical concepts in children with Spina Bifida.

Pre-school.

As with all children the type of activities in which they engage in the first few years of life are likely to have a crucial effect on their later performance in mathematics. In the case of the child with Spina Bifida some of the difficulties which arise based on lack of the right experiences in early life can be ameliorated to some extent if the parents follow the advice of the therapists who are likely to see the child at this stage. Advice will be given about encouraging movement and interaction as early as possible as this is well recognised as a serious factor in cognitive development(Tatlow 1980). As has already been mentioned the maturation of the nervous system is aided by activity and usage, and movement in the early years contributes to perceptual motor development generally(Field 1970a). The child learns to adapt to his world through the simultaneous use of his own senses and movement. This starts right from birth when the child begins to explore himself and his world and develops an awareness of both along with the ability to move in space and to move objects. Unfortunately the child with Spina Bifida spends a lot of the first years of life in hospital. However this situation should improve as it is likely that the children with Spina Bifida who do survive now will be less severely handicapped due to the selective non-treatment programmes(Sklayne 1981). Anderson and Spain(1977) recommend pre-school intervention in order to minimise the difficulties caused by neurological abnormalities, combined with deprivation of normal experiences. The use of playgroups and nursery school for the child as early as possible is very valuable. In these situations they will require a certain amount of structured, directed play.

In addition to the movement and interaction with objects that can be encouraged in these settings the child gets the chance to function among his peer group in a stimulating environment. This socialisation encourages the development of logical thought as they learn to see other children's points of view. Logical thinking is essential in mathematics.

Tew(1983) suggests that specific intervention programmes and home based pre-school teaching programmes may mitigate poor manual and spatial skills . He also advised that parents should be warned against being overprotective, a situation discussed by Bicknell as being likely to lead to underfunctioning.Tew(1983) also advocates giving parents suggestions of hierarchically arranged skills to practice with the child.

The Portage Guide to Early Education is one form of early intervention programme which has been predominantly home-based and mostly used with mentally handicapped children. It can however be used in schools and with other handicapped children as it consists of a lot of developmental checklists. Buckley(In Dessent 1984) suggests that it is possible that the gains in development shown by such programmes are due to a change of attitudes and expectations on the part of the parents and not directly as a result of the teaching. She suggests that the content of the programme may be of little importance. Lazar(1985) makes similar comments about some of the American Head-start programmes. Buckley states:-

> Perhaps the belief that the child is capable of learning and worth helping(implicitly conveyed in all intervention programmes), plus the support and understanding offered the parents , are the active ingredients producing change. Parents may be given hopes for the future and become more positive in their interaction with their child in a whole variety of ways.

For parents with a handicapped child support and positive suggestions are likely to prove invaluable.

Rosenbaum et al.(1975) tried a developmental intervention programme specifically aimed at the upper limb function of Spina Bifida children. Their programme was designed so that the parents could carry it out in their normal handling of the child. It was also aimed at helping the parents to appreciate the effects of motor impairment upon other areas of development. They felt that the results showed a definite benefit which came partly from the fact that the mothers became more confident in their handling of the child and welcomed having definite guidelines to follow. They also reported that the programme raised the parents expectations and changed their attitudes. It seems that specific suggestions are likely to be of more value than a general instruction to treat the child as normally as possible.

<u>School(from the age of five)</u>.

<u>Some problems of which teachers should be aware.</u>

Whatever efforts have been made with the child in the early years he may still reach the age of five at a lower functional level than his able bodied peers, and teachers need to be aware of the possible problem areas.

a) They must realise that the child with Spina Bifida is not simply a paraplegic but may have upper limb problems as well. Minns et al.(1977) felt that one of the causes of upper limb dysfunction was delayed maturation but they suspected that this persisted to some extent throughout life. This may well be partly due to the fact that the child has had to use his hands for propulsion, either on the floor or in a wheelchair, rather than using them in manipulative tasks. Wallace(1973) draws attention to the neurological abnormalities of the upper limbs which can cause problems of coordination.

b) Visual perceptual problems are likely to be present with 'figure-ground' and 'spatial' problems being very common. Strauss and Lehtinen(1947) state that distractibility which can show up as figure-ground problems is likely to occur in neurologically damaged individuals. Those children with Hydrocephalus have varying degrees of brain damage and often related ocular disorders as well.

c) Another major factor which could affect the child's concentration and performance in mathematics is the frequent urinary and shunt infections experienced by some of these children. This results in the child feeling generally below par and makes concentration difficult. In the special school the distractions caused by children moving in and out of the classroom for medical treatment can also make concentration difficult.

d) Teachers should beware of being misled by the child's good verbal skills which in the early years may be advanced for the child's age. This can give the appearance of intelligence and the fact that the child can learn words easily can suggest that he knows more than he does. In terms of pre-number and early number work it is necessary to know if the word is merely being parrotted or if it is attached to a concept.

The fact that the child is a good reader at an early age may cause the teacher to assume that the type of visual perceptual skills generally covered under pre-reading are no longer necessary, whereas they should be continued for pre-number work where this type of skill is more vital.

There is a tendency in schools to pay a lot more attention to reading readiness than to number readiness. Carr et al.(1981) suggest that children with Spina Bifida in normal schools perform better at maths than those in special schools due to an over-emphasis on reading related skills in the latter.

It should be remembered that there is much less redundancy in maths than in written language and it is therefore more difficult. In reading it is possible to guess words from the context.

If written number work is attempted based on the pseudo-counting which is frequently shown by the Spina Bifida child(and many others as well) then the subsequent maths is based on very shaky foundations as the essential contributary concepts are absent. Strict hierarchical development is not essential(Duncan 1978) but plenty of concept building, experimental and manipulative activity, before pencil and paper work, certainly is.

Pre-number activities.

Teachers need to be prepared to make a stand against parental pressure to do 'sums' until such time as they have given the child the chance to develop the important pre-number concepts. He needs to be able to classify and seriate and hopefully to conserve number before starting written work. On some occasions in order to allow the child to have the satisfaction of thinking that he is the same as the rest of the class it may be necessary to do simple sums before he conserves. If this is the case pre-number activities should continue to be covered for part of the time in such a way that the child does not feel that he is being singled out as incompetent. At all times the teacher needs to try and build up confidence in the children. Many of the remedial activities required for those children who have missed out at an early developmental stage can be carried out alongside some activities more suited to a later stage. It is really only at the end of the preoperational period mentioned by Piaget that children start to conserve and are able to develop a genuine concept of number. That is at about age six or seven . Number is a synthesis of logical operations and the child grasps the essential properties of number at the time that he is capable of genuine class and relation operations. A sequence of numbers results from an operational synthesis of classification and seriation.(Piaget 1941).

Movement as an aid to perceptual development.

In many cases it will be necessary to work through movement to aid perceptual development as this is likely to be an area in which the children have been restricted. Such movement should not be confined to the Physical Education lesson.

According to Kephart (1968) kinaesthetic figure-ground discrimination forms the basis for visual and auditory figure-ground discrimination. The former is an area in which children with Spina Bifida tend to be very weak. As the movement of an individual part of the body becomes differentiated from the mass and individual movements become purposefully made, the muscular effort going into this movement is greater than that going into the rest of the musculature. This movement becomes a figure against the ground and exercises which involve isolated movement of one body part emphasise figure ground as it applies to the individual. Differentiation is necessary for efficient movement and as the child learns to differentiate the parts of the body and elaborates and coordinates his movements he creates the possibility of increasing his perceptual abilities and his capacity to make his intellectual abilities known. Obviously for children who only have movement

in half of the body the emphasis must be on the functional part. Exercises for the arms, shoulders, wrists and fingers will be valuable both in this respect and that of improving upper limb strength and usage for daily living. If attempts are made to get the child walking with aids, and in those children who do have some use of their legs, the lower limbs will also be exercised and the children will be helped to develop a more normal view of the world by being on their feet rather than sitting all the time. Most of the children spend some time in an upright position in their early years as it is also beneficial to the circulation in the lower limbs and the working of the kidneys, although many will eventually be wheelchair bound.
Physical activities can also aid the development of hand-eye coordination, form constancy and spatial relationships. Spatial vocabulary such as above and below, also needs to be well established for future use in mathematics. Other perceptual activities should also be carried out.

Perceptual training – Selective attention.

Various schemes are available for perceptual training but these must be correctly used to be of any real benefit. Plodding through a lot of worksheets from a scheme such as that of Frostig without full use being made of all the suggested supplementary activities, and others which the teacher can think up, may result in the child developing an isolated skill but does not result in improved perceptual ability which the child can carry over to subjects such as maths. Teaching for transfer is necessary to link up the perceptual aspects of gross motor activities with more sedentary perceptual activities and with other subjects. The teacher needs to understand why he is doing perceptual work and how it influences other subjects if he is going to make it work.

One of the areas where children with Spina Bifida have the biggest problem, is, as has already been mentioned, in that of figure-ground discrimination. Such a child will appear to be inattentive and disorganised. This is because his attention tends to jump to any stimulus that intrudes upon him, no matter how irrelevant. He is unable to pick out the relevant details from among a mass(or what seems to him to be a mass) of information. Training in this area should result in an improved ability to shift attention appropriately, to concentrate upon relevant stimuli and ignore the irrelevant, to scan adequately and in general to exhibit more organised behaviour. A direct relevance of these points to maths can easily be seen as it is a subject where brief lapses of attention can cause a lot of problems due to the lack of redundancy of information.

Strauss and Lehtinen(1947) list distractibility as one of the main problems shown by children with neurological damage. Figure-ground discrimination problems are one way in which this manifests itself.

Pribram(1971) suggests that the process of attention involves the influence exerted by the inferior temporal 'association' cortex on the input mechanisms which adds further confirmation to the likelihood of the children with Hydrocephalus having such problems, as Tew et al.(1980) found.

In 1978 Tew had begun researching into this area by sending a questionnaire out to a large number of schools for the physically handicapped of which the school used for the case studies was one. The same school was used for trying out the teaching ideas. Considering the ratings for various problem areas as ranked by the teachers (N=11) within the school, impaired concentration came out top, followed by visual perception problems. It seems likely that these two areas are in fact linked. These results mirrored those from the total 175 teachers who replied.

Tew(1983) demonstrated significant positive relationships between estimated concentration span and mathematical ability in these children. this was at a much higher level than in any other subject.

In the research discussed in this study a Freedom from Distractibility Quotient(Sattler 1982) has been considered and appears to support the view that distractibility is a severe problem in many of these children and has an effect on the development of mathematical concepts.

Following the work on kinaesthetic figure-ground discrimination already mentioned, the following items of work on visual figure-ground skills may be found useful.

a) Discriminating objects in a room;e.g. round objects, blue objects. This can link with work on shape or colour.

b) Finding objects that are different;e.g. a round brick among square ones.

c) Sorting, with objects of two or more types to categorise. As the number of types increases the child has to shift attention appropriately. Sorting by several criteria is a more advanced way of doing this.

d) Working according to a plan and following instructions requires the focussing of attention.

e) Finding a specific object in a box of mixed objects.

f) Looking for a specific object when outside;e.g. the house with the blue door.

When it comes to dealing with this problem in mathematics, presenting the minimum amount of information at any one time and using squared paper where the recording of numbers is necessary can be of assistance. It is possible to link number work-sheets to the sort of figure-ground work-sheets which are available. Numbers can be hidden in pictures for identification by the pupil(see examples in Appendix 4).

It can be seen that perceptual training concentrates to a great extent on the developing of selective attention. This may be an area where the effects of both neurological damage and lack of early movement can be ameliorated to some extent.

The development of spatial awareness is important in terms of mathematical performance and this can be worked on, together with kinaesthetic figure-ground discrimination, in a movement setting. Additional activities can also be carried out relating the child to the space around him. This can start very simply by following simple maps of lines between dots and build up to further mapwork in the school grounds. These activities involve orientation of the child which is frequently lacking.Worksheets which involve copying lines between dots from simple to complex patterns, copying pegboard or cube patterns, copying pictures made of various shapes by using a stencil, and many other activities of this type all aid orientation and attention. In number work it is vital that a number such as 6 is written that way round and not as a 9, and in slightly more advanced work that 24 is not written as 42. Even more important is the necessity to have the concepts behind these numbers clearly set out in the mind.

Mathematics.

It is worth remembering that for a child with a deficit of attention the problem is made worse if he is given a task which of necessity divides his attention(Strauss and Lehtinen 1947). This may be the case with the motor response for children with poor coordination. Merely producing a row of figures correctly may be a task demanding the whole of the child's attention. Similarly the manipulation of some of the practical mathematics equipment could have the same effect. There are sets of structural apparatus available which are of a suitable size for children with manipulative problems(Stern 1953). Having numbers written on a card to put in the answer space of sums which have been written out for them may get them going if computation is the skill to be aimed for at that time. Once the answer has been checked by the teacher they can then copy the numbers from the card. Obviously the children need to learn to write the numbers themselves but it may be wise to get the mathematical concepts over separately at first and perhaps spend part of the lesson writing numbers as a separate skill. It is not suggested that excuses should be made for these children not to do certain written activities but it is important to analyse the task carefully and break it down into manageable parts. The major area of stimulation available to the child needs to be the task in hand and they must learn to concentrate on this. Distractions should be reduced to a minimum.

Most teachers are not specialists in mathematics and recently(1978-84) a number of mathematics schemes have been published which take that into consideration. Generally the schemes emphasise the hierarchical development of mathematical concepts and emphasise the importance of an adequate amount of pre-number work. There is an emphasis on the development of concepts rather than simply learning computation. The schemes have a lot of similarities and which scheme or schemes any school will choose to use will obviously be affected by the age-range involved and the personal preferences of the staff. As with perceptual training emphasis should not be given to the workbooks but to the practical activities which form an integral part of the schemes. It is very easy to start at the front of a pupil's book and work through it, with success being judged by the number of books completed rather than by the concepts developed. The teachers manuals form a very important part of most of the schemes.

For children with perceptual problems, such as those considered in this study it would seem wise to over emphasise the pre-number skills of classification, seriation and one-to-one correspondence, and try to ensure that conservation of number has been developed. Duncan(1978) suggests the use of a simple Piagetian conservation of number test to check this.

Duncan(1978) also suggests introducing the early numbers one to five and six to ten in random order so that the child gains understanding rather than merely the ability to say numbers in order, and this seems to be a good idea.

For children with perceptual problems the use of structural apparatus, such as that of Stern, is valuable. Stern(1953) described arithmetic as being a visuo-spatial problem and aimed at helping children to see the structure of numbers by means of the apparatus. A lot of pre-number work can be done using this apparatus in the sense that number concepts can be built up without the use of number names.

A combination of Stern structural apparatus and a scheme such as that of Duncan which is based on Piagetian principles would seem to be a useful basis for teaching early mathematics to these children , once pre-number concepts have been firmly established.

Chapter 8.- Summary.

Suggestions are made in this chapter as to how children with Spina Bifida might be helped to develop mathematical concepts.
The need for intervention at an early age is stressed (Field 1970a, Anderson and Spain 1977) in order to give the child the opportunity for as many of the normal movement and interaction activities as possible before he starts school, although the point is made that this sort of activity may still be needed when he does start school.
Various problems which may present in Spina Bifida children are mentioned for the benefit of teachers, particularly those in ordinary schools who may be inclined to see the child in a wheelchair as simply a paraplegic. These are the likelihood of upper limb dysfunction (Wallace 1973), visual perceptual problems(Miller and Sethi 1971) and frequent urinary tract or valve infections (Brocklehurst 1976).
A warning is given about being misled by the child's early verbal ability into overestimating his ability in other areas particularly maths(Zeiger and Orgel 1969).
The importance of a good grounding in pre-number concepts before moving on to formal number work, is stressed, with movement and perceptual training being discussed. The area of figure-ground discrimination is looked at in detail.
Mention is made of the large number of mathematics schemes produced in recent years which emphasise the hierarchical development of mathematical concepts and which are aimed at useage by non specialist maths teachers. A recommendation is made for using Stern structural mathematics with a scheme based on Piagetian principles, such as that of Duncan(1978), for children with perceptual problems. This would enable perceptual and maths work to go on alongside each other in an integrated fashion.
Early intervention can aid the problems caused by lack of a suitable environment for interaction and this may help the development of the brain. However it is likely to some extent that the brain damage occasioned by Hydrocephalus

will render the child less likely to be successful in mathematics, due to the generalised stretching of the cortex(Price 1976) which is likely to lead to distractibility. As it is likely that these children may develop concepts in mathematics at a later than normal age (Parfitt 1979) it is unwise to write them off early in life because they have great difficulty in this area. Although some of the children may never become numerate, with continued help others will succeed. It is important during the later years of their school life to try and relate what abilities they have to the mathematics they will need in later life.

CHAPTER NINE - CONCLUSION.

Conclusions.

Spina Bifida is a very complex condition in which the associated handicaps can occur in varying degrees of severity. This research has shown that the two main areas of disability which can occur in Myelomeningocele can affect the development of mathematical concepts. These are the neurological damage associated with the Hydrocephalus and the actual physical damage caused by the Spina Bifida lesion. Other factors, which relate to the child's environment, then interact with these variables.

Although this research looked at a large number of factors and their relationship to the development of mathematical concepts, it was not possible to identify any single variable as being the sole cause of problems in this area.

However, the effects of the neurological damage are likely to be more direct than those of physical handicap. Although the variables which are related to the degree of Hydrocephalus showed a relationship with arithmetic it seemed that the measures available were not sophisticated enough to give clear answers. Jackson and Lorber(1984) pointed out that estimates of the volume of cortex present in these children could not as yet be accurately worked out.
In the large scale data the presence of a shunt, which was taken to indicate the presence of Hydrocephalus, correlated highly significantly with mathematical ability. However, head circumference at birth and the ventricle-brain ratio did not reach the same level of significance. In the children with 'Congenital' Hydrocephalus the ventricle-brain ratio and the thickness of the neonatal pallium were not significantly related to ability in arithmetic. Nevertheless the severity of the neurological damage associated with the presence of Hydrocephalus is likely to be a major factor affecting the development of mathematical concepts. If Hydrocephalus is adequately controlled the unfortunate effects are likely to be reduced.
In the school based research, using the Young Group Mathematics Test, the results of the children with Spina Bifida suggested that they could cope with basic mechanical counting activities but had problems when it was necessary

to have an understanding of the concepts used and to reason out the methods needed to solve problems. It was also shown that other neurologically damaged children had similar problems.

Distractibility tends to be a characteristic of all neurologically damaged individuals(Strauss and Lehtinen 1947). Such persons will also tend to be stimulus bound and have problems in separating figure from ground. As mathematics is a subject where the attention must be kept strictly on the matter in hand in order to succeed, it seems likely that these characteristics could have a severe effect.

In the large scale research it seemed that a 'Freedom from Distractibility Quotient', which was worked out from the scores of three of the WISC sub-tests(Sattler 1982), could provide a useful explanation for some of the results shown by these children in arithmetic.

For instance some children with Myelomeningocele and shunts were in the top arithmetic group despite the fact that both this diagnosis and the presence of a shunt correlated negatively with ability in this subject(P=0.0001). It was necessary to be able to explain why some such children could perform well in this area. They were of higher overall intelligence but this did not seem to be a sufficient explanation on its own. These children showed a significant difference between Verbal and Performance IQ scores(P=0.01) with the means being 118.3(SD 13.2) and 91.1(SD 15.0) respectively. However the mean Freedom from Distractibility Quotient was 107 which may well compensate for the comparatively low Performance IQ.

In arithmetic Group 2 the same quotient may help to explain why the very small group of two Meningoceles are performing at a lower level in arithmetic than would be expected based on their IQs. The mean Full Scale IQ in this group is 90 whereas the mean Freedom from Distractibility Quotient is only 78. It is possible that the items involved in this quotient play a more important part in the development of mathematical concepts than do the remaining items on the Performance scale of the WISC.

There also seemed to be a link between the severity of the physical handicap and the results in arithmetic, which was supported by a high correlation between locomotion and arithmetic scores on the large scale data, both for those children with Spina Bifida and those with Congenital Hydrocephalus. The more mobile child is likely to have had more chance to build up spatial awareness by interaction with the environment. He is also likely to have spent a shorter time in hospital and missed less schooling. These factors are likely to affect development in mathematics.

The relatively poor performance IQs on the WISC have already been mentioned. In the children studied in detail the results on visuo-spatial measures were found to be related to ability in mathematics. The three children who performed at an average or above level in mathematics all had scores avove the 50th percentile on Raven's Coloured Progressive Matrices, and scores in the normal range on the Frostig Developmental Test of Visual Perception. The children who had good scores on the Crichton Vocabulary Scale but below average scores on Raven's Matrices and the Frostig Developmental Test of Visual Perception performed poorly in mathematics.

The interconnectedness of the two main areas of disability which can occur in Myelomeningocele was clearly shown by the large scale data. Reduced severity of physical handicap was frequently associated with less severe Hydrocephalus and therefore less likelihood of neurological damage.

Initial neurological damage can be lessened, to some degree, by efficient surgical techniques.
However the environment is a very important factor which can be altered to help the development of the child. The child needs to be encouraged to be as active as possible in his early years in order to help him to build up spatial awareness. In order for this to happen the parents may need support and guidance as to the sort of activities which may be suitable for their child at his stage of development. This sort of advice will often be given by therapists at the hospital where the child is treated. As he gets older

and starts to attend nursery school and then infant school he should be allowed to participate as fully as possible in normal school activities. If the child appears to have a shorter concentration span than the other children it may be necessary for an adult to help the child to sustain his interest in an activity. It may also be necessary to reduce the number of stimuli available to a manageable level, and to remove distractions. It is not easy to improve concentration span in a distractible child but work needs to start in this area at an early age. The earlier chapter on teaching mentions possible ways of helping to develop selective attention as the child moves through the school. As far as mathematics is concerned it is possible for teachers to feel that some of the children have problems which are insurmountable. However it seems likely that development, although delayed, may take place in a number of these children(Parfitt 1979) so care needs to be taken that an expectation of failure does not become a 'self fulfilling prophecy'. Pre-number concepts need to be developed and then the tasks required in mathematics should be analysed carefully so that they can be broken down into manageable parts. In this way the child has more chance of achieving success even though it may be a very slow process. For the children with difficulties in this area the aim should be to help them to reach a level where they can function in everyday life.

The future.

As a result of possible primary prevention(Smithells 1980), screening and selective non-treatment, the number of children with Spina Bifida, who reach school age, is declining. Those that do come into schools tend to be the less severely handicapped, both physically and intellectually.

Sklayne(1981) found that her 'post-selection' sample performed at a generally higher level in school than earlier samples which had been aggressively treated. The majority of the 'selected' children, especially with the introduction of the 1981 Education Act in April 1983, will be educated in mainstream schools. The fact that the best group of children

studied in the large scale data had a mean arithmetic score of 14 on the WISC, which roughly equates to a quotient of 120, shows that among these less handicapped, younger children there is a considerable amount of ability.
Even though the new generation of Spina Bifida children may be of higher intelligence, some specific problems in areas such as mathematics may occur, related to their physical and neurological condition.
It would be of value to the children if all those concerned with them could try and ensure that they are given the opportunities for the development of selective attention and spatial awareness, which have been mentioned earlier, as these seem to be essential attributes for the development of mathematical concepts. If this is followed by a carefully structured approach to the development of mathematical concepts, in which the task is broken down into small steps directed towards realistic goals, even those children who have difficulty should be able to make more satisfactory progress.

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APPENDIX 1.

The tests used in this study.

(This includes important points from the test manuals and comments on the tests.)

Daniels and Diack Reading Tests.

(The Standard Reading Tests. J.C.Daniels and H.Diack, Chatto and Windus 1972.)

The authors suggest that for reading the child requires sight(visual analysis), hearing(auditory analysis), and association of sight and sound. The test is based on the phonic approach to the teaching of reading and the understanding of the reading process.They further suggest that the extent of a child's vocabulary will influence his ability in reading. It seems that this is one of the factors that helps Spina Bifida children to succeed in this area. They also state that the child's score on any reading test depends not only on his reading ability and on the difficulty of the words in the test, but also upon the relationship of the method of teaching to the particular words included in the test. Daniels and Diack provide a battery of tests aimed at providing information on the child's problem areas. Many of the tests deal with what the authors class as pre-reading skills,so the child should succeed in them if normal progress in reading is to be expected. They recommend 80-100% success on the visual perception sections to be taken as a guide to the child's reading readiness. It would appear from some of the case studies that this is not in fact necessarily the case and that children with very weak visual perception can still do well at reading. This is possibly because of good phonic skills which show up well on a test such as that of Daniels and Diack. They present no empirical evidence to show that the additional tests of visual and auditory skills can give extra information as to why the child's reading is poor. As the Standard Reading Test is phonically based the link with visual perceptual skills seems to be very tenuous.

Copying abstract figures.

This is designed to discover something about the child's perceptual development and hand-eye coordination. The child needs to look at the inter-relationships of detailed parts, overall size and orientation.

Visual discrimination and orientation.

This is designed to determine what the child sees when he looks at pictures, diagrams and letters, and to pick out those who have not yet reached the stage of perceiving with left-right orientation, which is an important principle of identity. Again it is suggested that it will only be very poor readers who will have problems in this area.

Standard Test of Reading Skill.

This is a word recognition test in the form of short questions, which enables the child to get help from the context or form of the sentence. The child tends to think he is being marked on his answers to the questions. This test only goes up to a reading age of nine years which was surpassed very early on by some of the children. The Holborn Reading Scale was used for such children.

The Holborn Reading Scale.

(Manual; A.F.Watts 1970. George Harrup and Co.)

The Holborn Reading Scale claims to enable the tester to measure both word recognition and comprehension by using a single series of sentences containing a fine grading of these abilities.

The word recognition part of the scale has been used in this study. The child reads the sentences and the reading age given at the end of the sentence in which he records his fourth failure will indicate his reading age in years and months. The sentences are said to be arranged in order of difficulty both mechanically and as regards their comprehensibility.

Comments on the reading tests used in this study.

Neither the manual for the Daniels and Diack Standard Reading Test nor that for the Holborn Reading Scale contains details of studies of reliability or validity, and neither gives details as to how the sentences were constructed. Daniels and Diack claim that their reading test has been standardised so that it can be used to compare reading ages. They also state that:-

> In the grading of our tests we have abandoned the statistical method of determining a words difficulty for a difficulty grading in terms of reading skill involved in its recognition. Naturally we have only used words that are to be found in the spoken vocabulary of the children to be tested.

This sort of statement must be viewed with some caution as even in one class in one school the range of words in the spoken vocabulary of the children will be very varied. The Holborn Reading Scale sentences were constructed and tried out with children from $5\frac{1}{2}$ to 11 years of age and modified where necessary. After a preliminary standardisation it was used in 30 schools to get a fully representative sample for standardisation purposes. This included 200 children in each of ten half-yearly age groups from $5\frac{1}{2}$-$10\frac{1}{2}$. As the test was first used in 1948, although it was revised and copyrighted in 1980, the language is somewhat dated. However with both of these tests, because they are in sentence form, the child is given scope for the use of phonics, sight vocabulary, semantic and syntactic skills. In a graded word reading test it is not possible to make use of context, which inevitably gives a false impression about the level of functional reading. Although the Daniels and Diack manual suggests that these other skills have been considered in the grading of their sentences it is not made clear whether this is the case in the Holborn Reading Scale.

The Frostig Developmental Test of Visual Perception.
(Test Manual, M.Frostig, 1966.)
This test contains five sub-tests which can be scored separately. It has been critisised on the grounds that these are not clear cut areas, although it can still be of value and show specific areas of weakness by means of a perceptual age equivalent. The areas can also be combined to give a perceptual quotient.
The 5 sub-tests are as follows:-
1) Eye-motor coordination. A test of hand-eye coordination involving the drawing of continuous straight, curved or angled lines between boundaries of various widths or from point to point without guidelines.
2) Figure-ground discrimination. A test involving shifts in perception of figure against increasingly complex ground. Intersecting and hidden geometric figures are used.
3) Constancy of shape. A test involving the recognition of certain geometric figures presented in a variety of sizes, shadings and textures, and positions in space, and their discrimination from similar geometric figures. Circles, squares, rectangles, ellipses and parallelograms are used.
4) Position in space.
A test involving the discrimination of reversal and rotation of figures presented in series. Schematic drawings representing certain common objects are used.
5) Spatial relationships.
A test involving the analysis of simple forms and patterns. These consist of lines of various lengths and angles which the child is required to copy, using dots as guide points.

This is a test which has received a lot of critisism over the years as has the Frostig programme which is based on it. Frostig suggests that if children have problems of visual perception their perceptual training should form part of an integrated programme which includes sensory-motor, language, perceptual and conceptual skills, none of which can be dealt with successfully in isolation.

There is a separate standardisation document for this test (Frostig and Maslow 1964) which contains a very detailed account of the history of the construction of the test. Statistical data on over 2100 unselected nursery school and public school children from the age of three to nine years is summarised and test-retest and split-half reliability coefficients given. The test-retest produced a correlation coefficient of 0.80 for the perceptual quotient for a sample of 144 children retested after two weeks. The sub-test correlations ranged from 0.42 on Test 2 to 0.80 on Test 3. The comment is made that a low test-retest correlation could be expected on Test 1 as visuo-motor functioning is affected more than the other tests by the child's physical condition and emotional state at the time of the test.

This test has received a lot of critisism over the years. Sattler(1982) felt that it could be useful as a screening test of visual perception but was of no benefit as a guide to reading readiness. Sugden(in Levey and Goldstein 1984) also concluded that it was a good general test of visual perception but that the sub-tests did not measure discrete entities.

Smith and Marx(1973) carried out a factor analytic study and concluded that the test measures a single general factor of perceptual organisation which is weakly related to IQ, but unrelated to reading ability. Silverstein(1973) initially agreed, but after reanalysing his data he decided that it lent greater support to the premises upon which the Frostig test was constructed.

Tew(1976) drew similar conclusions to those of Smith and Marx but also felt that it was very largely a test of intelligence which needed to be used with care in Britain because the norms were American. He found correlations at the P= 0.001 level with WISC scores at the age of five and suggested that at this age it could give an approximate indication of intelligence. Tew(1983) also found that when Frostig results at the age of 5½ years were compared to attainments at the age of ten ,there was a high correlation among the children with Spina Bifida but not in the 'normal' controls. He suggests that results on the Frostig test can be used to predict later educational difficulty in this handicapped group.

Raven's Coloured Progressive Matrices and the Crichton Vocabulary Scale.

(Guide to using the coloured progressive matrices. J.C.Raven 1956. Guide to using the Crichton Vocabulary Scale with progressive matrices sets A, Ab and B. J.C.Raven 1961. Manual for Raven's progressive matrices and Crichton Vocabulary scale, Part 3 Section 7. 1976 J.C.Raven, J.H. Court, J.Raven. All H.K.Lewis.)

Raven's Matrices are designed to be a test of observation and clear thinking. By itself it is not a test of general intelligence and should be used in conjunction with a vocabulary scale. The Crichton Vocabulary Test is most commonly used with Raven's Matrices to give an overall picture. In the introduction Raven refers to this as a perceptual test.

The coloured matrices are arranged to assess mental development up to a stage where a person is sufficiently able to reason by analogy to adopt this way of thinking as a consistent method of inference. The manual suggests that this apparently decisive stage in intellectual maturation appears to be the one most likely to be impaired as a result of organic dysfunction. It further suggests that in the absence of stimulation the development of logical thinking tends to remain latent or develop somewhat later in life.

From experimental work leading to the construction of the matrices, Raven suggested that there are at least five qualitative developments in the order of intellectual activity:-

a) A child is first able to distinguish identical figures from different figures and later similar from dissimilar.

b) After this he is able to appreciate a figure's orientation with respect to himself and other objects in the perceptual field.

c) He can then perceive two or more discrete figures as forming a whole, or organised individual entity.

d) Subsequently he can analyse the perceived whole into its constituent elements or characters, and distinguish between what is given and what he himself contributes.

e) Finally he can compare analogous changes in the characters perceived and adopt this as a logical method of reasoning.

The matrices are presented in colour to hold the attention of young children. This makes the nature of the problem to be solved more obvious without in any way contributing to its solution. There is less of a figure-ground discrimination problem in the coloured matrices than occurs in the black and white version.

Raven(1961) states that the matrices indicate a person's present capacity for intellectual activity whatever knowledge he has acquired. The Crichton Vocabulary Test provides an index of his general cultural attainment. By using the two together instead of a single verbal test of general intelligence the two sides of the child's ability can be assessed separately.

In the Crichton Vocabulary Test the child is asked to explain, in his own words, the meaning of each word in turn. The child's immediate attention to what he is doing and care in selecting the one figure which completes a pattern correctly may influence his score on the matrices whereas his cultural amenities and educational opportunities are likely to influence his success in the vocabulary test. Raven also suggests that ill health affects attention more than recall and will thus affect the scores on the matrices more than on the vocabulary test. It is interesting to view the results of the Spina Bifida children in this light. Their attention may be affected by neurological damage but could also suffer from the various infections that many of these children get, affecting the shunt or the urinary tract.

In the revised manual Raven et al.(1976) state:-

> Special sections have been added to contribute to the questions of reliability and validity. It is not considered useful to cite a simple measure of reliability or validity for a test with such diverse applications. The setting in which the tests are administered appears to influence both validity and reliability.
> The use of age norms for the quantitative assessment of general mental development and the calculation of IQs is always questionable.

The original standardisation was carried out in Dumfries in 1949-50 but since then Raven had used the tests with large groups of people of all ages. He found a correlation of 0.94 between the matrices and the vocabulary test for a group of 60 children including 10 from each half yearly age group

from five to ten years inclusive.
Sattler(1982) describes Raven's Matrices as a useful supplementary measure of non-verbal intelligence which is likely to be less culturally biased than most intelligence tests. However he does criticise the fact that it measures cognitive ability through the process of figural reasoning only.

<u>The English Picture Vocabulary Test.</u>
(Manual, M.A.Brimer and L.M.Dunn. 1962. Educational Evaluation Enterprises, Bristol.)

This test was designed to assess the levels of listening vocabulary between the ages of 5 years and 11 years 11 months but the manual suggests that it can be more generally interpreted as a measure of verbal ability. The child is given a word orally and four pictures from which he selects the correct one, by pointing. It differs from many other vocabulary tests by being functionally independent of reading skill. It could be said that visual perception plays a part in the test but the authors claim that this has been reduced to a minimum:-

a) The picture is focussed on the essential attribute to which the word refers.
b) Distractors were avoided which depended for their operation upon differences in degree of representational accuracy.
c) The pictures are clear line drawings of high quality.
d) Shadow images are avoided by the use of good paper.
e) The distraction of facing pages is avoided.

However it still seems possible that the drawings will be difficult for the child to distinguish as they are in black and white only.
This is really a test of receptive language whereas the Crichton vocabulary scale requires expressive language. Guesswork is possible in this test as it is only necessary to point to a picture.
The EPVT was derived from the American Peabody Picture Vocabulary Test and was standardised in Wiltshire on a large number of children. The full details of reliability and validity studies were due to be produced in an interpretative manual which had still not appeared at the time of writing(1984). Ryan(in Levey and Goldstein 1984) suggests that this test could be useful as an IQ estimate for children with restricted speech.

The Goodenough Draw-a-Man Test.

(Measurement of intelligence by drawings. F.L.Goodenough. 1926. World Book Co. New York. Children's drawings as a measure of intellectual ability. D.B.Harris. 1963, Harcourt & Brace.)

This is based on the notion that any child in any culture will have seen a man and is used to gain an insight into conceptual development with an element of motor development. Such a test cannot be compared with a full I Q test such as W I S C but can provide some interesting information. The results were validated with normal children of 5-8 years and is said to give a guide to approximate mental age.

Comments have been made on this test in the case study section where a number of drawings are included.

D.B.Harris (1963) produced a revision and extension of this test ,detailed in Children's Drawings as Measures of Intellectual Maturity, and added further information on this subject.

He stated that intellectual maturity is the ability to form concepts of increasingly abstract character and that intellectual ability requires three abilities:-

a) The ability to perceive (to discriminate likenesses and differences).

b) The ability to abstract (to classify such objects according to the likenesses and differences).

c) The ability to generalise (to assign an object newly experienced to a correct class according to discriminated features, properties or attributes).

These three factors taken together comprise the process of concept formation.

The scales given in this revision of the test are drawn up to reflect the differences between the drawings of boys and girls. For instance girls are said to show more detail while boys show better proportions, and boys may exaggerate the limbs while girls exaggerate the head and trunk.

He points out that not everyone would agree with the idea that the drawing of a man gives any idea of the body image of the drawer but mentions that Goldworth (1950) suggested that the body image idea may be valid for those persons who are not highly 'visual' and depend primarily on other modalities,for instance kinaesthetic, for their perceptions. In a culture such as ours the visual mode of perception is the dominant one.

It seems possible that children with severe visual perceptual problems will have difficulty on the Draw-a-Man Test particularly when they have a physical handicap which will result in a distorted body image built from the kinaesthetic modality. In addition the conceptual element must be remembered.

Harris(1963) considers the reliability and validity of the test and quotes McCarthy(1944) who gave the test to 386 third and fourth graders with a week in between each test. He found test-retest reliability of 0.68 with a high correlation of 0.90 between markers. Harris investigated the effect on the performance in this test in children who had been taught by an art teacher. He found that those children were not consistently different to the others. In general the artistic drawings scored more points for clothing items but the others scored better on the correct placement of body parts.

It seems that this can be a useful supplementary test but must inevitably be affected by the level of motor control.

<u>The Bender-Gestalt Test for Young Children. E.M.Koppitz.</u>
(Grune and Stratton 1964)

The child is given a large sheet of blank paper and a series of shapes to copy. This is scored according to a large number of criteria and gives a Bender age from which it is stated that a rough IQ can be calculated.
Sattler(1982) suggests that it is really only a test of perceptuo-motor ability.
The test manual states that the test can be used to suggest the possibility of brain damage and emotional problems.
Further advice would be necessary if the results suggested brain damage in 'normal' children but in a study of children with Spina Bifida and Hydrocephalus such indications would be expected.
Strauss and Lehtinen(1947) suggest that number concepts depend on the perception of objects in space combined with the ability to organise as indicated by the 'Gestalt school. It therefore seems likely that the results on this test should relate to the results on both the maths test and the spatial parts of the Frostig Developmental Test of visual perception. In physically handicapped children the problem of motor control when drawing may pre-occupy the child and affect the finished product.
Broadhurst and Phillips(1969) urge caution in the use of this test due to the fact that they found a great discrepancy between different scorers. They studied a representative sample of 127 Birmingham school children of approximately eleven years of age and administered the Bender-Gestalt Test along with cognitive and achievement tests. They then used four independent scorers, who were all psychologists, to score the test using the Koppitz system.The results were examined for inter-scorer reliability, which was found to be lacking. They also suggest that British norms are needed having found the following results:-

	Broadhurst	Koppitz
Mean error score	2.24(SD 2.1)	1.50(SD 2.1)
Number of children	127	31
Age of children	10y9m-11y3m	10y6m-10y11m

Broadhurst's mean error score was significantly higher than that of Koppitz but was for a larger sample who may well have covered a larger intellectual range.

The worrying fact in the research by Broadhurst was that the mean error score differed considerably when the tests were scored by the four examiners. The mean error scores were:- 2.0 ; 1.84 ; 3.76 ; 2.0.

It would seem wise to heed the caution of Broadhurst and Phillips and not attach to much weight to the results of this test.

The Weschler Intelligence Scale for Children.

This is the test which was used at Sheffield Children's Hospital from which the large scale data was obtained. It is also the test most frequently used in research due to the fact that it has both verbal and performance scales with a number of sections in each enabling results to be broken down into various areas. As with any test there are critics. Wedell(1973) states that factorial studies have shown that the verbal scale is a fairly representative measure of language skill but only two sub-tests of the performance scale(Block design and object assembly) have appreciable loadings on factors relating to sensory and motor organisation. He suggests that the motor scale is based on a far too heterogeneous set of tests to justify using it as a measure of sensory and motor organisation.
It could also be suggested that the arithmetic sub-test should form part of the performance rather than the verbal scale.
The mean for the test is 100 with a standard deviation of 15. The author suggests that one standard deviation difference between the verbal and performance scores is important although a 12 point difference is significant at the 5% level. The mean for the sub-tests (scaled scores) is 10 with a standard deviation of 3 and a maximun possible of 19.
<u>The sub-tests are as follows</u>:-
<u>Verbal scale</u>.
<u>Information</u> General knowledge- answering questions orally.
<u>Similarities.</u> The child says in what way two given items are alike.
<u>Arithmetic.</u> The first 15 problems are read to the child, the last three he reads himself.
This test requires accurate auditory reception, auditory memory, visualisation, mental manipulation, the ability to keep several facts in the mind simultaneously and an understanding of numerical relationships.
<u>Vocabulary.</u> The child is asked the meanings of words.

Comprehension. Problems are posed and the child supplies the answers.

Digit Span. The child repeats a series of digits after the examiner. In the 2nd part he repeats them backwards.

Performance scale.

Picture completion. The child is shown pictures and says what is missing. This requires memory for detail, ability to scan and to perceive logical inconsistencies in a visual medium.

Picture arrangement. The child is given 3-5 pictures and has to arrange them in the right order to make a story.

Block design. The child copies designs from models or cards using red and white blocks.

Object assembly. Jigsaws of familiar objects.e.g.apple.

Coding. This is a test of hand speed filling in a code on a sheet.

Mazes. Drawing the path out of a maze.

Sattler(1982) describes this as one of the best intelligence tests available and found its norms, reliability and validity to be excellent.

Tew and Laurence(1974) in a study of the validity of the WISC with children with Spina Bifida compared the scores of 57 cases administered at five year intervals. They found a highly significant correlation indicating that stability rather than variability is characteristic of the IQ scores of children with malformations of the central nervous system. The sample included 16 meningoceles, 32 Myelomeningoceles and 9 Encephaloceles.

The vast majority of the tests used in the large scale data from Sheffield are the WISC or the equivalent for young children, the WPPSI. A few children have been tested on developmental scales, such as the Vineland Social Maturity Scale and this is not directly comparable to an IQ score, although a rough assessment can be made from it.

APPENDIX TWO.

The results obtained by the children considered in the case studies.

Part (a) The Young Group Mathematics Test.

Results of Young Mathematics Test.

Child A.

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1. Largest.	✓	✓	✓	✓
2. Counting 3, how many.	✓	✓	✓	✓
3. Count, subtract 2.	x	✓	✓	✓
4. Sequence by 1's.	✓	✓	✓	✓
5. Divide by 2.	x	✓	✓	✓
6. Count, another 1.	✓	✓	✓	✓
7. Shape constancy.	✓	x	✓	✓
8. $\frac{1}{2}$, how many left.	x	x	x	✓
9. Twice as many.	x	x	✓	✓
10. Spatial relationships.	✓	x	x	✓
11. Place value.	x	x	✓	x
12. $\frac{3}{4}$. Full.	x	x	x	✓
13. Sequence by 3's.	x	x	x	✓
14. Middle sized.	x	✓	✓	✓
15. Figure ground.	x	✓	✓	✓

Computation Section.

Side A. Addition.	5	8	8	11
Side B. Subtraction.	4	6	6	9

(both out of 15.)

Results of Young Mathematics Test.

Child A .

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1.Most.	✓	✓	✓	✓
2.Count,subtract 1.	✓	✓	✓	✓
3.Figure ground.	✓	✓	✓	✓
4.Count,x2,other side.	x	✓	✓	✓
5.½,relationship to x2.	x	✓	✓	✓
6.Ordination,5th.	x	x	✓	✓
7.1-1 correspondence.	x	✓	x	✓
8.Addition,x10,place value.	x	x	x	✓
9.Telling time.	x	x	x	x
10.Shape constancy.	x	x	✓	✓
11.Figure ground,bigger, smaller.	x	✓	x	✓
12.Twice as many,all together.	x	x	x	x
13.Counting in perspective.	x	✓	x	✓
14.Theoretical subtraction.	x	x	x	x
15.Odd and even numbers.	x	x	x	x

Chronological Age.	8y1m	9y	9y8m	10y8m
Maths. Age.	6.3y	7.2y	7.5y	8.4y
Maths. Quotient.	79	80	77	80

Results of Young Mathematics Test.

Child B .

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1. Largest.	✓	✓	✓	✓
2. Counting 3, how many.	✓	✓	✓	✓
3. Count, subtract 2.	✓	✓	✓	✓
4. Sequence by 1's.	✓	✓	✓	✓
5. Divide by 2.	✓	✓	✓	✓
6. Count, another 1.	✓	✓	✓	✓
7. Shape constancy.	✓	✓	✓	✓
8. $\frac{1}{2}$, how many left.	x	✓	✓	✓
9. Twice as many.	✓	x	✓	✓
10. Spatial relationships.	x	✓	✓	✓
11. Place value.	x	✓	✓	✓
12. $\frac{3}{4}$. Full.	✓	x	✓	✓
13. Sequence by 3's.	x	✓	✓	x
14. Middle sized.	✓	x	x	x
15. Figure ground.	x	x	✓	x

Computation Section.

	1978	1979	1980	1981
Side A. Addition.	6	9	10	14
Side B. Subtraction.	5	9	12	13

(both out of 15.)

Results of Young Mathematics Test.

Child B.

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1. Most.	✓	✓	✓	✓
2. Count, subtract 1.	✓	✓	✓	✓
3. Figure ground.	✓	✓	✓	✓
4. Count, x2, other side.	✓	✓	✓	✓
5. ½, relationship to x2.	✓	✓	✓	✓
6. Ordination, 5th.	✓	✓	✓	✓
7. 1-1 correspondence.	✓	✓	✓	✓
8. Addition, x10, place value.	✓	✓	✓	✓
9. Telling time.	x	x	✓	x
10. Shape constancy.	x	x	✓	✓
11. Figure ground, bigger, smaller.	✓	✓	✓	✓
12. Twice as many, all together.	✓	✓	✓	x
13. Counting in perspective.	x	✓	✓	✓
14. Theoretical subtraction.	x	✓	✓	✓
15. Odd and even numbers.	x	x	✓	✓

Chronological Age.	7y9m	8y9m	9y4m	10y4m
Maths. Age.	7.3y	8.1y	9y	9.1y
Maths. Quotient.	94	91	97	91

Results of Young Mathematics Test.

Child C .

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1.Largest.	✓	✓	✓	✓
2.Counting 3,how many.	✓	✓	✓	✓
3.Count,subtract 2.	✓	✓	✓	✓
4.Sequence by 1's.	✓	✓	✓	✓
5.Divide by 2.	✓	✓	✓	✓
6.Count,another 1.	✓	✓	✓	✓
7.Shape constancy.	✓	✓	✓	✓
8.$\frac{1}{2}$,how many left.	✓	✓	✓	✓
9.Twice as many.	✓	x	✓	✓
10.Spatial relationships.	x	✓	✓	✓
11.Place value.	✓	✓	✓	✓
12. $\frac{3}{4}$. Full.	x	✓	✓	✓
13.Sequence by 3's.	x	✓	✓	✓
14.Middle sized.	x	x	✓	✓
15.Figure ground.	x	✓	✓	x

Computation Section.

Side A. Addition.	13	15	15	15
Side B. Subtraction.	11	13	14	14

(both out of 15.)

Results of Young Mathematics Test.

Child C .

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1.Most.	✓	✓	✓	✓
2.Count,subtract 1.	✓	✓	✓	✓
3.Figure ground.	✓	✓	✓	✓
4.Count,x2,other side.	✓	✓	✓	✓
5.½,relationship to x2.	✓	✓	✓	✓
6.Ordination,5th.	✓	✓	✓	✓
7.1-1 correspondence.	✓	✓	✓	✓
8.Addition,x10,place value.	✓	✓	✓	✓
9.Telling time.	✓	✓	✓	✓
10.Shape constancy.	✓	✓	✓	✓
11.Figure ground,bigger, smaller.	x	✓	✓	✓
12.Twice as many,all together.	✓	x	✓	✓
13.Counting in perspective.	x	x	✓	x
14.Theoretical subtraction.	x	✓	✓	✓
15.Odd and even numbers.	x	x	x	✓

Chronological Age.	7y4m	8y3m	8y10m	9y10m
Maths. Age.	8.4y	9.3y	+10.1	+9.9
Maths. Quotient.	120	115	+114	+100

Results of Young Mathematics Test.
Child D.

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1. Largest.	✓	✓	✓	✓
2. Counting 3, how many.	✓	✓	✓	✓
3. Count, subtract 2.	✓	✓	✓	✓
4. Sequence by 1's.	✓	✓	✓	✓
5. Divide by 2.	x	x	x	x
6. Count, another 1.	✓	✓	✓	✓
7. Shape constancy.	✓	x	✓	✓
8. $\frac{1}{2}$, how many left.	x	x	x	x
9. Twice as many.	x	x	✓	x
10. Spatial relationships.	x	✓	x	x
11. Place value.	x	✓	x	✓
12. $\frac{3}{4}$. Full.	x	✓	x	x
13. Sequence by 3's.	x	x	x	x
14. Middle sized.	x	x	✓	x
15. Figure ground.	x	x	✓	x

Computation Section.

Side A. Addition.	3	6	7	11
Side B. Subtraction.	4	7	7	8

(both out of 15.)

Results of Young Mathematics Test.

Child D.

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1.Most.	✓	✓	✓	✓
2.Count,subtract 1.	x	✓	✓	✓
3.Figure ground.	✓	✓	✓	✓
4.Count,x2,other side.	x	x	x	✓
5.½,relationship to x2.	x	x	x	✓
6.Ordination,5th.	x	✓	x	✓
7.1-1 correspondence.	x	✓	✓	✓
8.Addition,x10,place value.	x	x	✓	✓
9.Telling time.	✓	x	✓	✓
10.Shape constancy.	✓	✓	x	✓
11.Figure ground,bigger, smaller.	✓	✓	✓	✓
12.Twice as many,all together.	x	x	x	x
13.Counting in perspective.	x	✓	x	✓
14.Theoretical subtraction.	x	x	x	x
15.Odd and even numbers.	x	x	x	x

Chronological Age.	7y9m	8y9m	9y5m	10y5m
Maths. Age.	6.3y	7.1y	7.2y	7.9y
Maths. Quotient.	82	82	77	78

Results of Young Mathematics Test.
Child E.

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1. Largest.	✓	✓	✓	✓
2. Counting 3, how many.	✓	x	✓	✓
3. Count, subtract 2.	✓	✓	✓	✓
4. Sequence by 1's.	✓	✓	✓	✓
5. Divide by 2.	x	✓	✓	✓
6. Count, another 1.	✓	✓	✓	✓
7. Shape constancy.	✓	x	✓	✓
8. $\frac{1}{2}$, how many left.	✓	✓	x	x
9. Twice as many.	✓	✓	x	x
10. Spatial relationships.	x	x	✓	✓
11. Place value.	x	x	✓	x
12. $\frac{3}{4}$. Full.	x	x	x	x
13. Sequence by 3's.	x	x	x	x
14. Middle sized.	x	x	x	x
15. Figure ground.	✓	✓	x	x

Computation Section.

Side A. Addition.	4	7	8	13
Side B. Subtraction.	1	5	5	7

(both out of 15.)

Results of Young Mathematics Test.

Child E.

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1.Most.	✓	✓	✓	✓
2.Count,subtract 1.	✓	✓	✓	✓
3.Figure ground.	✓	✓	✓	✓
4.Count,x2,other side.	✓	✓	✓	✓
5.½,relationship to x2.	✓	✓	✓	✓
6.Ordination,5th.	x	x	✓	✓
7.1-1 correspondence.	✓	x	✓	✓
8.Addition,x10,place value.	x	x	✓	✓
9.Telling time.	✓	✓	x	✓
10.Shape constancy.	x	x	x	✓
11.Figure ground,bigger, smaller.	x	x	x	✓
12.Twice as many,all together.	x	x	✓	x
13.Counting in perspective.	x	x	x	x
14.Theoretical subtraction.	x	x	x	✓
15.Odd and even numbers.	x	x	x	x

Chronological Age.	7y8m	8y8m	9y4m	10y4m
Maths. Age.	6.5y	6.9y	7.2y	7.9y
Maths. Quotient.	85	80	77	79

Results of Young Mathematics Test.
Child F.

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1. Largest.	✓	✓	✓	✓
2. Counting 3, how many.	✓	✓	✓	✓
3. Count, subtract 2.	✓	✓	✓	✓
4. Sequence by 1's.	✓	✓	✓	✓
5. Divide by 2.	x	✓	✓	✓
6. Count, another 1.	x	✓	✓	✓
7. Shape constancy.	✓	✓	✓	✓
8. $\frac{1}{2}$, how many left.	x	x	x	✓
9. Twice as many.	✓	x	x	✓
10. Spatial relationships.	x	x	x	✓
11. Place value.	x	x	x	✓
12. $\frac{3}{4}$. Full.	x	✓	x	x
13. Sequence by 3's.	x	x	x	x
14. Middle sized.	x	x	x	x
15. Figure ground.	x	x	x	x

Computation Section.

Side A. Addition.	5	6	7	10
Side B. Subtraction.	3	4	7	7

(both out of 15.)

Results of Young Mathematics Test.

Child F.

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1.Most.	✓	✓	✓	✓
2.Count,subtract 1.	x	✓	✓	✓
3.Figure ground.	✓	✓	✓	✓
4.Count,x2,other side.	x	✓	✓	✓
5.½,relationship to x2.	x	x	✓	✓
6.Ordination,5th.	✓	x	✓	✓
7.1-1 correspondence.	✓	✓	✓	✓
8.Addition,x10,place value.	x	x	x	✓
9.Telling time.	✓	x	x	✓
10.Shape constancy.	x	✓	x	✓
11.Figure ground,bigger, smaller.	x	✓	✓	x
12.Twice as many,all together.	x	x	x	x
13.Counting in perspective.	x	x	x	x
14.Theoretical subtraction.	x	x	x	x
15.Odd and even numbers.	x	x	x	x

Chronological Age.	7y8m	8y8m	9y3m	10y3m
Maths. Age.	6.4y	6.7y	7.1y	7.2y
Maths. Quotient.	84	78	77	71

Results of Young Mathematics Test.

Child G .

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1. Largest.	✓	✓	✓	✓
2. Counting 3, how many.	✓	✓	✓	✓
3. Count, subtract 2.	✓	✓	✓	✓
4. Sequence by 1's.	✓	✓	✓	✓
5. Divide by 2.	✓	✓	✓	✓
6. Count, another 1.	✓	✓	✓	✓
7. Shape constancy.	✓	✓	✓	✓
8. $\frac{1}{2}$, how many left.	✓	✓	✓	✓
9. Twice as many.	x	x	✓	✓
10. Spatial relationships.	✓	✓	✓	✓
11. Place value.	x	✓	✓	✓
12. $\frac{3}{4}$. Full.	x	✓	✓	✓
13. Sequence by 3's.	x	✓	✓	✓
14. Middle sized.	x	x	x	✓
15. Figure ground.	x	✓	✓	✓

Computation Section.

Side A. Addition.	10	14	12	15
Side B. Subtraction.	11	13	12	12

(both out of 15.)

Results of Young Mathematics Test.

Child G .

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1.Most.	✓	✓	✓	✓
2.Count,subtract 1.	✓	✓	✓	✓
3.Figure ground.	✓	✓	✓	✓
4.Count,x2,other side.	✓	✓	✓	✓
5.½,relationship to x2.	✓	✓	✓	✓
6.Ordination,5th.	✓	✓	✓	✓
7.1-1 correspondence.	✓	✓	✓	✓
8.Addition,x10,place value.	✓	✓	✓	✓
9.Telling time.	✓	x	✓	✓
10.Shape constancy.	✓	x	✓	✓
11.Figure ground,bigger, smaller.	✓	✓	✓	✓
12.Twice as many,all together.	x	x	✓	✓
13.Counting in perspective.	x	✓	✓	✓
14.Theoretical subtraction.	✓	x	✓	✓
15.Odd and even numbers.	x	✓	✓	✓

Chronological Age.	7y6m	8y6m	9y1m	10y1m
Maths. Age.	8.2y	9.0y	9.3y	+9.9y
Maths. Quotient.	111	106	101	+100

Results of Young Mathematics Test.

Child H.

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1. Largest.	✓	x	✓	✓
2. Counting 3, how many.	✓	✓	✓	✓
3. Count, subtract 2.	x	x	x	x
4. Sequence by 1's.	x	x	x	x
5. Divide by 2.	x	x	x	x
6. Count, another 1.	x	x	✓	✓
7. Shape constancy.	x	x	x	✓
8. $\frac{1}{2}$, how many left.	x	x	x	x
9. Twice as many.	x	x	x	x
10. Spatial relationships.	x	x	x	x
11. Place value.	x	x	x	x
12. $\frac{3}{4}$. Full.	x	x	x	x
13. Sequence by 3's.	x	x	x	x
14. Middle sized.	x	x	x	x
15. Figure ground.	x	x	x	x

Computation Section.

	1978	1979	1980	1981
Side A. Addition.	0	2	1	1
Side B. Subtraction.	0	1	1	4

(both out of 15.)

Results of Young Mathematics Test.

Child H.

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1.Most.	✓	✓	x	x
2.Count, subtract 1.	x	✓	x	✓
3.Figure ground.	x	✓	✓	✓
4.Count, x2, other side.	x	x	x	x
5.½, relationship to x2.	x	✓	x	x
6.Ordination, 5th.	x	x	x	✓
7.1-1 correspondence.	x	x	x	x
8.Addition, x10, place value.	x	x	x	x
9.Telling time.	x	x	x	x
10.Shape constancy.	✓	✓	x	x
11.Figure ground, bigger, smaller.	x	x	x	x
12.Twice as many, all together.	x	x	x	x
13.Counting in perspective.	x	x	x	x
14.Theoretical subtraction.	x	x	x	x
15.Odd and even numbers.	x	x	x	x

Chronological Age.	7y7m	8y8m	9y1m	10y1m
Maths. Age.	-5.5	5.8y	5.5y	5.9y
Maths. Quotient.	-68	68	56	-60

Results of Young Mathematics Test.

Child I.

Oral Side A. (success ✓, failure x.)

Concepts involved	1978	1979	1980	1981
1. Largest.	✓	✓	Died.	
2. Counting 3, how many.	✓	✓		
3. Count, subtract 2.	✓	x		
4. Sequence by 1's.	x	✓		
5. Divide by 2.	x	x		
6. Count, another 1.	x	x		
7. Shape constancy.	✓	✓		
8. $\frac{1}{2}$, how many left.	x	x		
9. Twice as many.	x	x		
10. Spatial relationships.	x	✓		
11. Place value.	x	x		
12. $\frac{3}{4}$. Full.	x	x		
13. Sequence by 3's.	x	x		
14. Middle sized.	x	x		
15. Figure ground.	x	x		

Computation Section.

	1978	1979
Side A. Addition.	2	1
Side B. Subtraction.	1	2

(both out of 15.)

Results of Young Mathematics Test.

Child I .

Oral Side B. (success ✓, failure x.)

Concepts involved.	1978	1979	1980	1981
1.Most.	✓	✓	Died.	
2.Count,subtract 1.	✓	✓		
3.Figure ground.	✓	✓		
4.Count,x2,other side.	x	x		
5.½,relationship to x2.	x	x		
6.Ordination,5th.	x	x		
7.1-1 correspondence.	x	x		
8.Addition,x10,place value.	x	x		
9.Telling time.	x	x		
10.Shape constancy.	✓	✓		
11.Figure ground,bigger, smaller.	✓	x		
12.Twice as many,all together.	x	x		
13.Counting in perspective.	x	x		
14.Theoretical subtraction.	x	x		
15.Odd and even numbers.	x	x		

Chronological Age.	8y	9y
Maths. Age.	5.9y	5.9y
Maths. Quotient.	75	66

APPENDIX TWO.

The results obtained by the children considered in the case studies.

Part (b) The battery of tests.

Test Results Child A.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	8y1m	9y	9y8m	10y8m
	Maths.Age.	6.3y	7.2y	7.5y	8.4y
	Maths.Quotient.	79	80	77	78
	Percentile.	9th	10th	7th	8th
Daniels and Diack Reading or Holborn.	Chron.Age.	7y9m	9y	9y8m	
	Reading Age.	6y	6.7y	7.1y	
	Reading Quot.	77	74	71	
	Percentile.	8th	2nd	3rd	
Frostig D.T.V.P.	Chron.Age.	8y1m	9y	9y8m	
	Perceptual Qu.	73	72	80	
	Percentile.	4th	4th	10th	
	Sub scale age equivalents.				
	I Eye-Motor.	6y	6y	6y3m	
	II Fig-Ground.	4y6m	5y9m	6y6m	
	III Shape Cons.	8y3m	9y	9y	
	IV Pos.in Space	6y3m	7y	7y	
	V Spatial Rel.	6y6m	6y6m	7y6m	
Bender Gestalt.	Chron.Age.	8y1m		9y8m	
	Bender Age.	5y2m		5y6m	
	Indicators of 'S'	11		9	
	Brain Damage.'HS'	1		1	
	Percentile.	-1st		-1st	
E.P.V.T.	Chron.Age.	8y1m			
	Vocabulary Age.	7y			
	Percentile.	19th			
Raven's Coloured Progressive Matrices.	Chron.Age.	8y1m	9y	9y8m	
	Grade.	III	IV	III-	
	Description.	I.Av.	-Av.	I.Av.	
	Percentile.	50th	10-25	25th	

Test Results Child A.(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	8y1m	9y	9y8m	
	Grade.	III	III	IV-	
	Description.	V.Av.	V.Av.	-Av.	
	Percentile.	25-50	25-50	10th	
Draw a Man.	Chron.Age.	8y1m			
	Mental Age.	8y9m			
	Percentile.	34th			
Conservation.	Number.	NO		YES	
	Mass.	NO		YES	
Daniels and Diack V.P.	Abs.Figures.	0/4			
	Orientation.	15/19			

Abbreviations used:-

	Chron.Age	-	Chronological Age.
	Quot./Qu.	-	Quotient.
Frostig,	Fig.	-	Figure.
	Cons.	-	Constancy.
	Pos.	-	Position.
	Rel.	-	Relationships.
Bender,	S	-	Significant.
	HS	-	Highly Significant.
D & D,	Abs.	-	Abstract.
Raven and Crichton.	Av.	-	Average.
	I.	-	Intellectually.
	V.	-	Verbally.
	-	-	Below.
	+	-	Above.
	S.	-	Superior.

Test Results Child B.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	7y9m	8y9m	9y4m	10y4m
	Maths.Age.	7.3y	8.1y	9y	9.1y
	Maths.Quotient.	94	91	97	91
	Percentile.	30th	29th	45th	30th
Daniels and Diack Reading or Holborn.	Chron.Age.	7y5m	8y9m	9y4m	
	Reading Age.	8.3y	8.9y	9.9y	
	Reading Quot.	112	101	105	
	Percentile.	80th	50th	65th	
Frostig D.T.V.P.	Chron.Age.	7y9m	8y9m	9y4m	
	Perceptual Qu.	89	92	82	
	Percentile.	23rd	30th	14th	
	Sub scale age equivalents.				
	I Eye-Motor.	7y	10+y	6y9m	
	II Fig.Ground.	8y3m	8y3m	8y3m	
	III Shape Cons.	8y3m	9y	9y	
	IV Pos.in Space	6y3m	5y6m	6y3m	
	V Spatial Rel.	6y6m	8y3m	7y6m	
Bender Gestalt.	Chron.Age.	7y8m		9y4m	
	Bender Age.	6y4m		6y6m	
	Indicators of 'S'	4		5	
	Brain Damage.'HS'	2		1	
	Percentile.	16th		2nd	
E.P.V.T.	Chron.Age.	7y9m			
	Vocabulary Age.	7y1m			
	Percentile.	32nd			
Raven's Coloured Progressive Matrices.	Chron.Age.	7y9m	8y9m	9y4m	
	Grade.	III-	III	III+	
	Description.	I.Av.	Av.	Av.	
	Percentile.	50th	50th	50-75	

Test Results Child B.(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	7y9m	8y9m	9y4m	
	Grade.	I	II	II+	
	Description.	V.S.	+Av.	+Av.	
	Percentile.	+95th	90th	90th	
Draw a Man.	Chron.Age.	7y9m			
	Mental Age.	9y6m			
	Percentile.	50th			
Conservation.	Number.	YES			
	Mass.	YES			
Daniels and Diack V.P.	Abs.Figures.	$\frac{3}{4}$			
	Orientation.	$\frac{18}{19}$			

Abbreviations used:-

	Chron.Age	-	Chronological Age.
	Quot./Qu.	-	Quotient.
Frostig,	Fig.	-	Figure.
	Cons.	-	Constancy.
	Pos.	-	Position.
	Rel.	-	Relationships.
Bender,	S	-	Significant.
	HS	-	Highly Significant.
D & D,	Abs.	-	Abstract.
Raven and Crichton.	Av.	-	Average.
	I.	-	Intellectually.
	V.	-	Verbally.
	-	-	Below.
	+	-	Above.
	S.	-	Superior.

Test Results Child Q.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	7y4m	8y3m	8y10m	9y10m
	Maths.Age.	8.4y	9.3y	+10.1	+9.9
	Maths.Quotient.	120	115	+114	+100
	Percentile.	90th	85th	+85th	+50th
Daniels and Diack Reading or Holborn.	Chron.Age.	6y11m	8y3m	8y10m	
	Reading Age.	7y	11.3y	12.9y	
	Reading Quot.	101	136	143	
	Percentile.	51st	+99th	+99th	
Frostig D.T.V.P.	Chron.Age.	7y3m	8y3m	8y10m	
	Perceptual Qu.	97	88	92	
	Percentile.	40th	23rd	31st	
	Sub scale age equivalents.				
	I Eye-Motor.	7y	5y9m	7y	
	II Fig.Ground.	5y9m	6y6m	7y	
	III Shape Cons.	7y6m	8y3m	9y	
	IV Pos.in Space	7y	8y9m	8y9m	
	V Spatial Rel.	8y3m	8y3m	8y3m	
Bender Gestalt.	Chron.Age.	7y2m		8y10m	
	Bender Age.	7y3m		+11y	
	Indicators of 'S'	3		0	
	Brain Damage.'HS'	0		0	
	Percentile.	50th		95th	
E.P.V.T.	Chron.Age.	7y3m			
	Vocabulary Age.	8y4m			
	Percentile.	76th			
Raven's Coloured Progressive Matrices.	Chron.Age.	7y3m	8y3m	8y10m	
	Grade.	III	III	II+	
	Description.	I.Av.	I.Av.	+Av.	
	Percentile.	50th	50th	90th	

Test Results Child C.(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	7y3m	8y3m	8y10m	
	Grade.	II+	II+	I	
	Description.	+Av.	+Av.	V.S.	
	Percentile.	90th	+90th	95th	
Draw a Man.	Chron.Age.	7y3m			
	Mental Age.	10y			
	Percentile.	90th			
Conservation.	Number.	YES		YES	
	Mass.	NO		YES	
Daniels and Diack V.P.	Abs.Figures.	3/4			
	Orientation.	19/19			

Abbreviations used:-

	Chron.Age	-	Chronological Age.
	Quot./Qu.	-	Quotient.
Frostig,	Fig.	-	Figure.
	Cons.	-	Constancy.
	Pos.	-	Position.
	Rel.	-	Relationships.
Bender,	S	-	Significant.
	HS	-	Highly Significant.
D & D,	Abs.	-	Abstract.
Raven and Crichton.	Av.	-	Average.
	I.	-	Intellectually.
	V.	-	Verbally.
	-	-	Below.
	+	-	Above.
	S.	-	Superior.

Test Results Child D.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	7y9m	8y9m	9y5m	10y4m
	Maths.Age.	6.3y	7.1y	7.2y	7.9y
	Maths.Quotient.	82	82	77	78
	Percentile.	15th	15th	7th	8th
Daniels and Diack Reading or Holborn.	Chron.Age.	7y9m	8y9m	9y5m	
	Reading Age.	5.8y	7.9y	8.6y	
	Reading Quot.	75	90	89	
	Percentile.	5th	20th	21st	
Frostig D.T.V.P.	Chron.Age.	7y9m	8y9m	9y5m	
	Perceptual Qu.	-65	70	58	
	Percentile.	-1st	3rd	-1st	
	Sub scale age equivalents.				
	I Eye-Motor.	4y9m	5y9m	5y9m	
	II Fig.Ground.	4y3m	4y6m	4y9m	
	III Shape Cons.	5y6m	7y6m	6y3m	
	IV Pos.in Space	4y9m	7y	5y6m	
	V Spatial Rel.	6y	6y	5y6m	
Bender Gestalt.	Chron.Age.	7y9m		9y5m	
	Bender Age.	5y2m		5y5m	
	Indicators of 'S'	7		8	
	Brain Damage.'HS'	2		3	
	Percentile.	-1st		-1st	
E.P.V.T.	Chron.Age.	7y9m			
	Vocabulary Age.	7y			
	Percentile.	27th			
Raven's Coloured Progressive Matrices.	Chron.Age.	7y9m	8y9m	9y5m	
	Grade.	V	V	IV-	
	Description.	I.Def.	I.Def.	-Av.	
	Percentile.	5th	5th	10th	

Test Results Child D.(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	7y9m	8y9m	9y5m	
	Grade.	II	III+	III+	
	Description.	+Av.	V.Av.	V.Av.	
	Percentile.	75-90	50-75	50th	
Draw a Man.	Chron.Age.	7y9m			
	Mental Age.	6y			
	Percentile.	3rd			
Conservation.	Number.	NO		NO	NO
	Mass.	NO		NO	YES
Daniels and Diack V.P.	Abs.Figures.	0/4			
	Orientation.	14/19			

Abbreviations used:-

	Chron.Age	-	Chronological Age.
	Quot./Qu.	-	Quotient.
Frostig,	Fig.	-	Figure.
	Cons.	-	Constancy.
	Pos.	-	Position.
	Rel.	-	Relationships.
Bender,	S	-	Significant.
	HS	-	Highly Significant.
D & D,	Abs.	-	Abstract.
Raven and Crichton.	Av.	-	Average.
	I.	-	Intellectually.
	V.	-	Verbally.
	-	-	Below.
	+	-	Above.
	S.	-	Superior.
	Def.	-	Defective.

Test Results Child E.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	7y8m	8y8m	9y4m	10y4m
	Maths.Age.	6.5y	6.9y	7.3y	7.9y
	Maths.Quotient.	85	80	78	79
	Percentile.	18th	10th	8th	9th
Daniels and Diack Reading or Holborn.	Chron.Age.	7y4m	8y8m	9y4m	
	Reading Age.	+9y	11.9y	13.3y	
	Reading Quot.	+120	130	143	
	Percentile.	90th	90th	+99th	
Frostig D.T.V.P.	Chron.Age.	7y8m	8y8m	9y4m	
	Perceptual Qu.	90	84	80	
	Percentile.	25th	15th	10th	
	Sub scale age equivalents.				
	I Eye-Motor.	9y6m	6y9m	7y	
	II Fig.Ground.	5y3m	7y	7y	
	III Shape Cons.	7y6m	9y	9y	
	IV Pos.in Space	5y6m	6y3m	6y3m	
	V Spatial Rel.	6y6m	8y3m	8y3m	
Bender Gestalt.	Chron.Age.	7y8m		9y4m	
	Bender Age.	6y6m		7y3m	
	Indicators of 'S'	5		4	
	Brain Damage.'HS'	0		0	
	Percentile.	16th		6th	
E.P.V.T.	Chron.Age.	7y8m			
	Vocabulary Age.	7y1m			
	Percentile.	34th			
Raven's Coloured Progressive Matrices.	Chron.Age.	7y8m	8y8m	9y4m	
	Grade.	III-	III-	IV	
	Description.	I.Av.	I.Av.	-Av.	
	Percentile.	25th	25-50	10-25	

Test Results Child E .(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	7y8m	8y8m	9y4m	
	Grade.	II	III+	III	
	Description.	+Av.	V.Av	V.Av	
	Percentile.	80th	50-75	50th	
Draw a Man.	Chron.Age.	7y8m			
	Mental Age.	8y			
	Percentile.	27th			
Conservation.	Number.	NO		YES	YES
	Mass.	NO		NO	YES
Daniels and Diack V.P.	Abs.Figures.	2/4			
	Orientation.	19/19			

Abbreviations used:-

	Chron.Age	- Chronological Age.
	Quot./Qu.	- Quotient.
Frostig,	Fig.	- Figure.
	Cons.	- Constancy.
	Pos.	- Position.
	Rel.	- Relationships.
Bender,	S	- Significant.
	HS	- Highly Significant.
D & D,	Abs.	- Abstract.
Raven and Crichton.	Av.	- Average.
	I.	- Intellectually.
	V.	- Verbally.
	-	- Below.
	+	- Above.
	S.	- Superior.

Test Results Child F.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	7y8m	8y8m	9y3m	10y3m
	Maths.Age.	6.4y	6.7y	7.1y	7.2y
	Maths.Quotient.	84	78	77	71
	Percentile.	18th	8th	7th	3rd
Daniels and Diack Reading or Holborn.	Chron.Age.	7y4m	8y8m	9y3m	
	Reading Age.	6.9y	7y	8y	
	Reading Quot.	94	81	86	
	Percentile.	30th	10th	19th	
Frostig D.T.V.P.	Chron.Age.	7y8m	8y8m	9y3m	
	Perceptual Qu.	85	86	92	
	Percentile.	15th	15th	31st	
	Sub scale age equivalents.				
	I Eye-Motor.	6y9m	7y3m	+10y	
	II Fig.Ground.	5y9m	8y3m	8y3m	
	III Shape Cons.	6y9m	7y	7y6m	
	IV Pos.in Space	6y3m	7y	8y9m	
	V Spatial Rel.	7y6m	7y6m	7y6m	
Bender Gestalt.	Chron.Age.	7y7m		9y3m	
	Bender Age.	10y9m		8y1m	
	Indicators of 'S'	1		3	
	Brain Damage.'HS'	0		1	
	Percentile.	84th		18th	
E.P.V.T.	Chron.Age.	7y7m			
	Vocabulary Age.	7y1m			
	Percentile.	37th			
Raven's Coloured Progressive Matrices.	Chron.Age.	7y8m	8y8m	9y3m	
	Grade.	IV	III-	III	
	Description.	?Av.	I.Av.	I.Av.	
	Percentile.	25th	25th	25-50	

Test Results Child F.(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	7y8m	8y8m	9y3m	
	Grade.	III+	III+	III+	
	Description.	V.Av	V.Av	V.Av.	
	Percentile.	50-75	50-75	50-75	
Draw a Man.	Chron.Age.	7y7m			
	Mental Age.	8y6m			
	Percentile.	32nd			
Conservation.	Number.	NO		YES	YES
	Mass.	NO		NO	YES
Daniels and Diack V.P.	Abs.Figures.	3/4			
	Orientation.	19/19			

Abbreviations used:-

	Chron.Age	-	Chronological Age.
	Quot./Qu.	-	Quotient.
Frostig,	Fig.	-	Figure.
	Cons.	-	Constancy.
	Pos.	-	Position.
	Rel.	-	Relationships.
Bender,	S	-	Significant.
	HS	-	Highly Significant.
D & D,	Abs.	-	Abstract.
Raven and Crichton.	Av.	-	Average.
	I.	-	Intellectually.
	V.	-	Verbally.
	-	-	Below.
	+	-	Above.
	S.	-	Superior.

Test Results Child G.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	7y6m	8y6m	9y1m	10y1m
	Maths.Age.	8.2y	9.0y	9.3y	10.1y
	Maths.Quotient.	111	106	101	100
	Percentile.	80th	65th	51st	50th
Daniels and Diack Reading or Holborn.	Chron.Age.	7y2m	8y6m	9y1m	
	Reading Age.	+9y	12.6y	13.3y	
	Reading Quot.	+126	144	147	
	Percentile.	+95th	+99th	+99th	
Frostig D.T.V.P.	Chron.Age.	7y6m	8y6m	9y1m	
	Perceptual Qu.	121	90	98	
	Percentile.	93rd	28th	47th	
	Sub scale age equivalents.				
	I Eye-Motor.	+10y	+10y	8y6m	
	II Fig.Ground.	8y3m	7y	8y3m	
	III Shape Cons.	9y	8y3m	9y	
	IV Pos.in Space	7y	7y	8y9m	
	V Spatial Rel.	8y3m	8y3m	8y3m	
Bender Gestalt.	Chron.Age.	7y5m		9y1m	
	Bender Age.	10y9m		+11y	
	Indicators of 'S'	0		0	
	Brain Damage.'HS'	0		0	
	Percentile.	84th		93rd	
E.P.V.T.	Chron.Age.	7y5m			
	Vocabulary Age.	10y1m			
	Percentile.	95th			
Raven's Coloured Progressive Matrices.	Chron.Age.	7y6m	8y6m	9y1m	
	Grade.	II	II+	II+	
	Description.	+Av.	+Av.	+Av.	
	Percentile.	75-90	90th	90th	

Test Results Child G.(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	7y6m	8y6m	9y1m	
	Grade.	I	I	I	
	Description.	V.S.	V.S.	V.S.	
	Percentile.	95th	95th	95th	
Draw a Man.	Chron.Age.	7y6m			
	Mental Age.	11y6m			
	Percentile.	84th			
Conservation.	Number.	YES			
	Mass.	YES			
Daniels and Diack V.P.	Abs.Figures.	4/4			
	Orientation.	18/19			

Abbreviations used:-

	Chron.Age	-	Chronological Age.
	Quot./Qu.	-	Quotient.
Frostig,	Fig.	-	Figure.
	Cons.	-	Constancy.
	Pos.	-	Position.
	Rel.	-	Relationships.
Bender,	S	-	Significant.
	HS	-	Highly Significant.
D & D,	Abs.	-	Abstract.
Raven and Crichton.	Av.	-	Average.
	I.	-	Intellectually.
	V.	-	Verbally.
	-	-	Below.
	+	-	Above.
	S.	-	Superior.

Test Results Child H.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	7y7m	8y	9y3m	10y3m
	Maths.Age.	-5.5y	5.8y	5.5y	5.9y
	Maths.Quotient.	-68	68	56	-60
	Percentile.	-1st	2nd	-1st	-1st
Daniels and Diack Reading or Holborn.	Chron.Age.	7y4m	8y8m	9y3m	
	Reading Age.	5.2y	5.8y	6.1y	
	Reading Quot.	71	64	66	
	Percentile.	3rd	-1st	-1st	
Frostig D.T.V.P.	Chron.Age.	7y7m	8y8m	9y3m	
	Perceptual Qu.	-65	62	58	
	Percentile.	-1st	-1st	-1st	
	Sub scale age equivalents.				
	I Eye-Motor.	4y9m	5y9m	6y	
	II Fig.Ground.	3y	4y6m	4y9m	
	III Shape Cons.	3y6m	6y	7y	
	IV Pos.in Space	4y9m	7y	5y	
	V Spatial Rel.	4y9m	4y9m	5y	
Bender Gestalt.	Chron.Age.	7y7m		9y3m	
	Bender Age.	-5y		-5y	
	Indicators of 'S'	10		11	
	Brain Damage.'HS'	4		3	
	Percentile.	-1st		-1st	
E.P.V.T.	Chron.Age.	7y8m			
	Vocabulary Age.	7y1m			
	Percentile.	34th			
Raven's Coloured Progressive Matrices.	Chron.Age.	7y8m	8y8m	9y3m	
	Grade.	V	IV-	V	
	Description.	I.Def	-Av.	I.Def	
	Percentile.	5th	10th	-5th	

Test Results Child H.(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	7y8m	8y8m	9y3m	
	Grade.	V	V	V	
	Description.	V.Def	V.Def	V.Def	
	Percentile.	-5th	-5th	-5th	
Draw a Man.	Chron.Age.	7y7m			
	Mental Age.	6y3m			
	Percentile.	6th			
Conservation.	Number.	NO		NO	NO
	Mass.	NO		NO	NO
Daniels and Diack V.P.	Abs.Figures.	0/4			
	Orientation.	12/19			

Abbreviations used:-

	Chron.Age	- Chronological Age.
	Quot./Qu.	- Quotient.
Frostig,	Fig.	- Figure.
	Cons.	- Constancy.
	Pos.	- Position.
	Rel.	- Relationships.
Bender,	S	- Significant.
	HS	- Highly Significant.
D & D,	Abs.	- Abstract.
Raven and Crichton.	Av.	- Average.
	I.	- Intellectually.
	V.	- Verbally.
	-	- Below.
	+	- Above.
	S.	- Superior.
	Def.	- Defective.

Test Results Child I.

		1978	1979	1980	1981
Young Maths. Test.	Chron.Age.	8y	9y		
	Maths.Age.	5.9y	5.9y		
	Maths.Quotient.	75	66		
	Percentile.	5th	1st		
Daniels and Diack Reading or Holborn.	Chron.Age.	8y	9y		
	Reading Age.	6.1y	6.1y		
	Reading Quot.	77	68		
	Percentile.	6th	-1st		
Frostig D.T.V.P.	Chron.Age.	8y	9y		
	Perceptual Qu.	69	78		
	Percentile.	2nd	10th		
	Sub scale age equivalents.				
	I Eye-Motor.	5y9m	6y3m		
	II Fig.Ground.	5y3m	7y		
	III Shape Cons.	6y3m	9y		
	IV Pos.in Space	5y6m	7y		
	V Spatial Rel.	6y	7y6m		
				1979	
Bender Gestalt.	Chron.Age.	8y	8y3m	8y8m	9y3m
	Bender Age.	6y6m	-5y	7y3m	7y3m
	Indicators of 'S'	4	10	3	4
	Brain Damage.'HS'	1	1	1	1
	Percentile.	15th	-1st	15th	6th
E.P.V.T.	Chron.Age.	8y2m			
	Vocabulary Age.	7y			
	Percentile.	19th			
Raven's Coloured Progressive Matrices.	Chron.Age.	8y2m	9y		
	Grade.	IV	IV-		
	Description.	-Av.	-Av.		
	Percentile.	25th	10th		

Test Results Child I.(cont.)

		1978	1979	1980	1981
Crichton. Vocabulary Scale.	Chron.Age.	8y2m	9y		
	Grade.	V	V		
	Description.	V.Def	V.Def		
	Percentile.	5th	-5th		
Draw a Man.	Chron.Age.	8y			
	Mental Age.	6y9m			
	Percentile.	5th			
Conservation.	Number.	NO			
	Mass.	NO			
Daniels and Diack V.P.	Abs.Figures.	2/4			
	Orientation.	18/19			

Abbreviations used:-

	Chron.Age	- Chronological Age.
	Quot./Qu.	- Quotient.
Frostig,	Fig.	- Figure.
	Cons.	- Constancy.
	Pos.	- Position.
	Rel.	- Relationships.
Bender,	S	- Significant.
	HS	- Highly Significant.
D & D,	Abs.	- Abstract.
Raven and Crichton.	Av.	- Average.
	I.	- Intellectually.
	V.	- Verbally.
	-	- Below.
	+	- Above.
	S.	- Superior.
	Def.	- Defective.

(The tests at 8years were carried out just before a spate of valve operations, those at 8y2m just afterwards.)

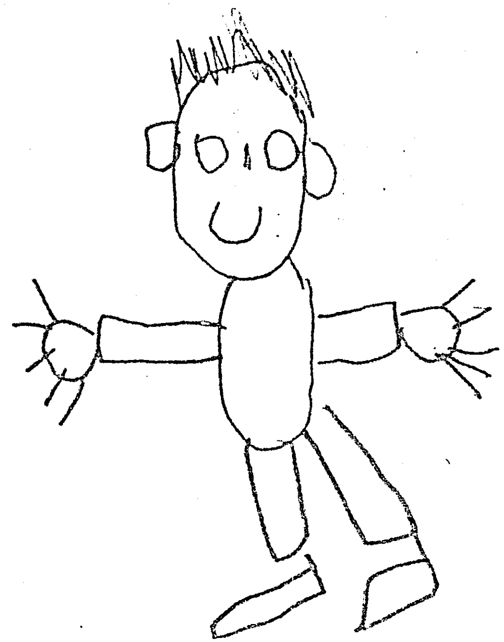
Results obtained from the additional children in 1979.
(2 of the children were also tested in 1978 and these results are shown in parenthesis.)

	Child (iii)	Child (iv)	Child (v)	Child (vi)
Chron.Age.	10y2m (8y9m)	10y (8y7m)	9y8m	9y7m
Maths.Age.	7.3y (5.9y)	7.1y (6.3y)	7.8y	8.4y
Maths.Quot.	71(66)	71(74)	79	85
Reading Age.	8.6y (6.7y)	13y (8.8y)	8.4y	8.4y
Reading Quot.	84(77)	130(100)	86	86
Frostig.Quot.	84(96)	80(76)	88	78
Sub-scores				
(i)	6y9m	6y3m	+10y	6y9m
(ii)	8y3m	7y	7y	6y
(iii)	9y	9y	9y	7y
(iv)	8y9m	8y9m	7y	8y9m
(v)	8y3m	7y6m	8y3m	8y3m
Raven grade.	III	IV-	II	III
Percentile.	50th	10th	75th	50th
Crichton gr.	III-	III+	II	IV
Percentile.	25-50	50-75	90th	5th
E.P.V.T.Perc.	42nd	73rd	68th	25th
Bender Perc.	2nd (2nd)	17th (5th)	60th	-1st
Brain damage.	6 (11)	2 (6)	1	8
Draw a man	5th	5th	29th	14th
Piaget				
Number	No	No	Yes	Yes
Mass	No	No	Yes	No

APPENDIX THREE.

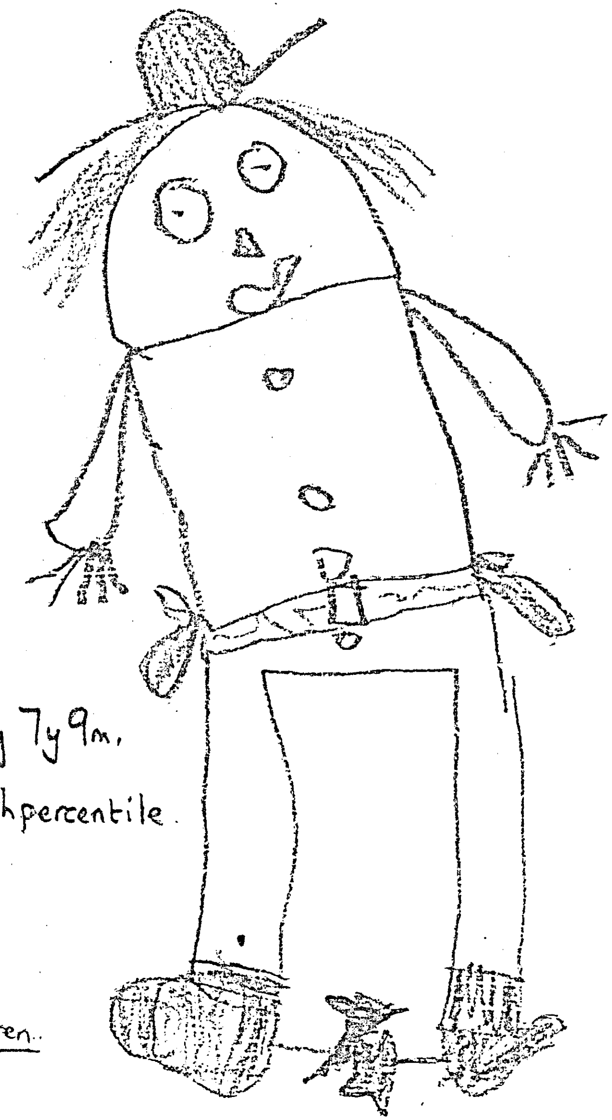
Examples of Draw-a-Man tests, as mentioned in Chapter 6.

Child A.



Boy 8y. 1m.
34th percentile

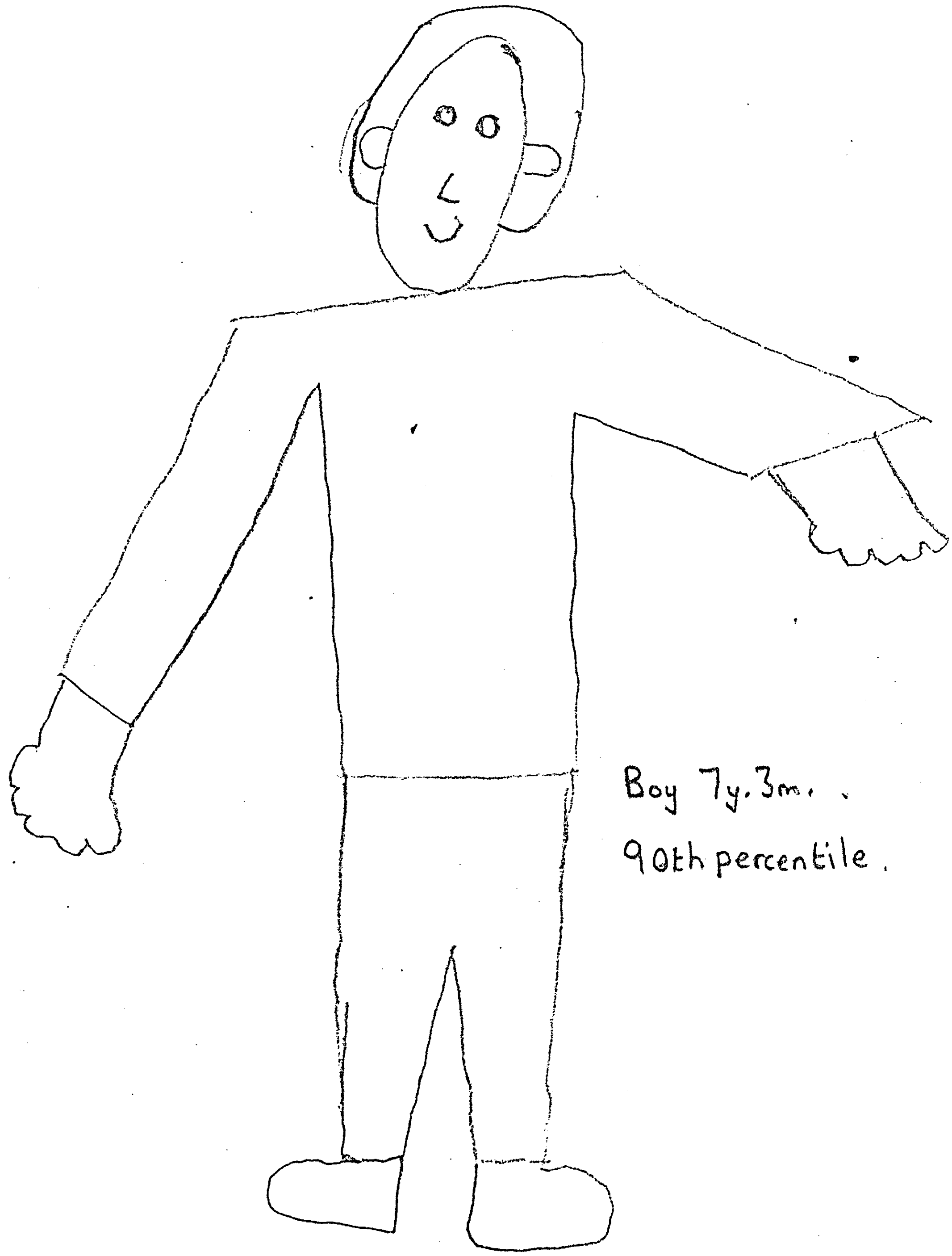
Child B.



Boy 7y 9m.
50th percentile

Case Study Children.

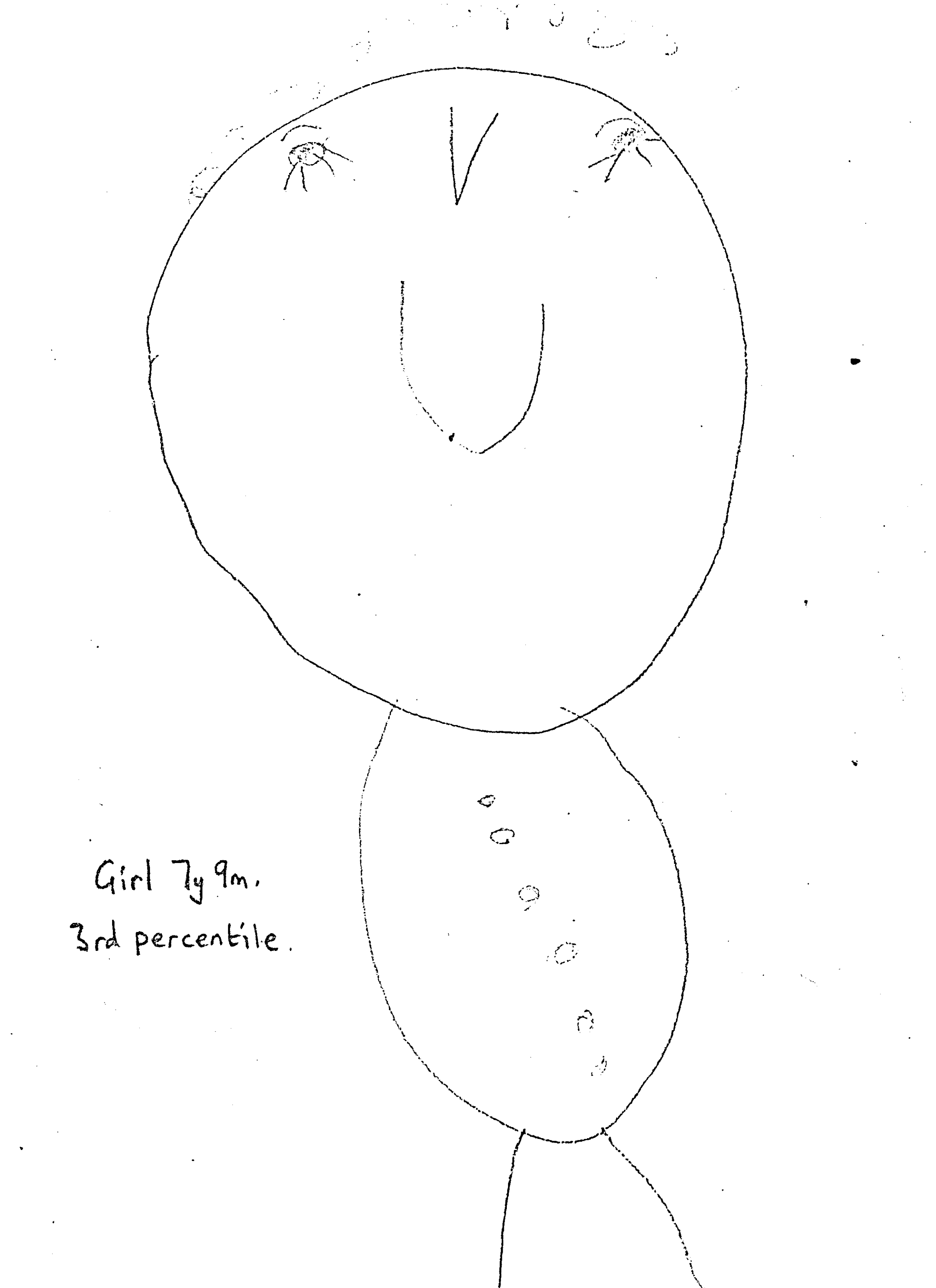
Case Study
Child. C.



Boy 7y. 3m.
90th percentile.

Case Study

Child D

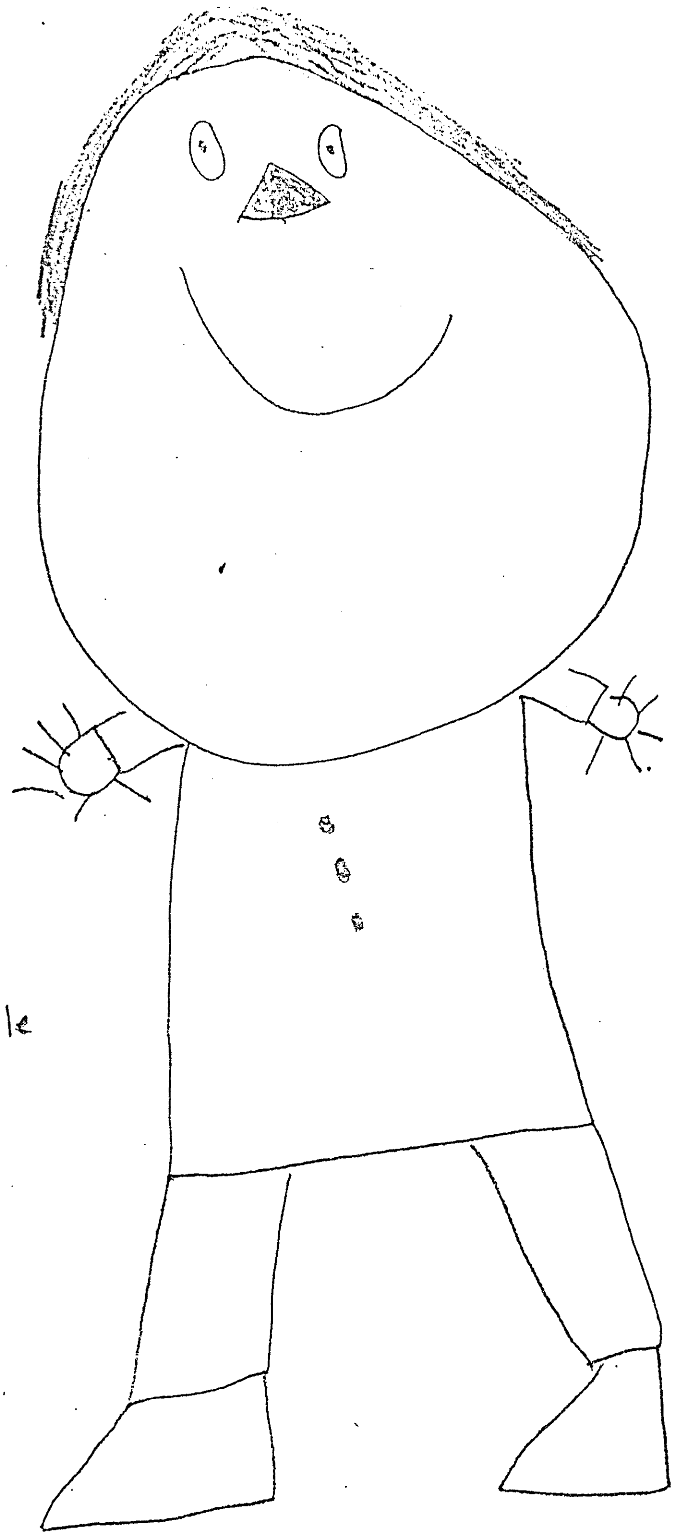


Girl 7y 9m.

3rd percentile.

Case Study

Child E.



Girl 7y 8m.

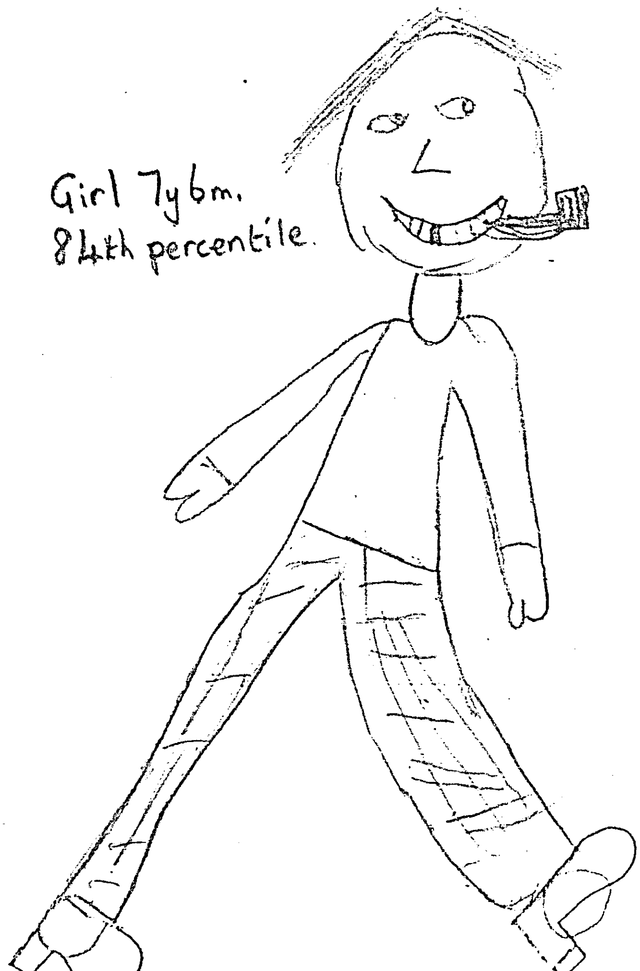
27th percentile

Case study children

Child F.

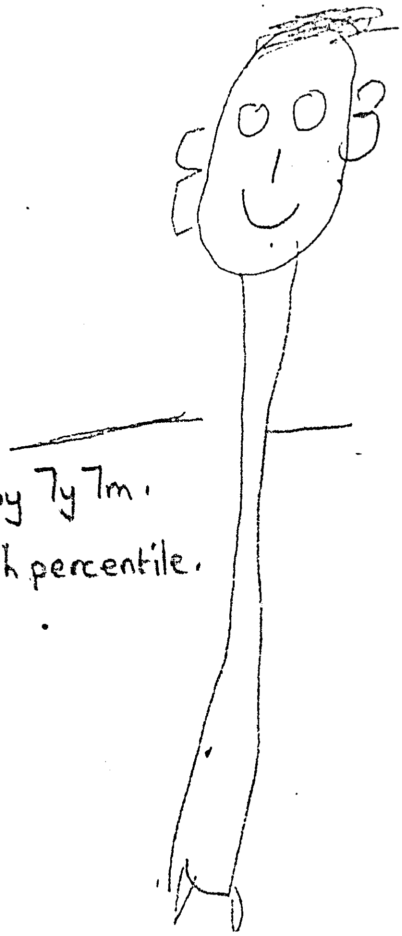
Girl 7y 7m.
32nd percentile.

Child G.



Girl 7y 6m.
84th percentile.

Child H.

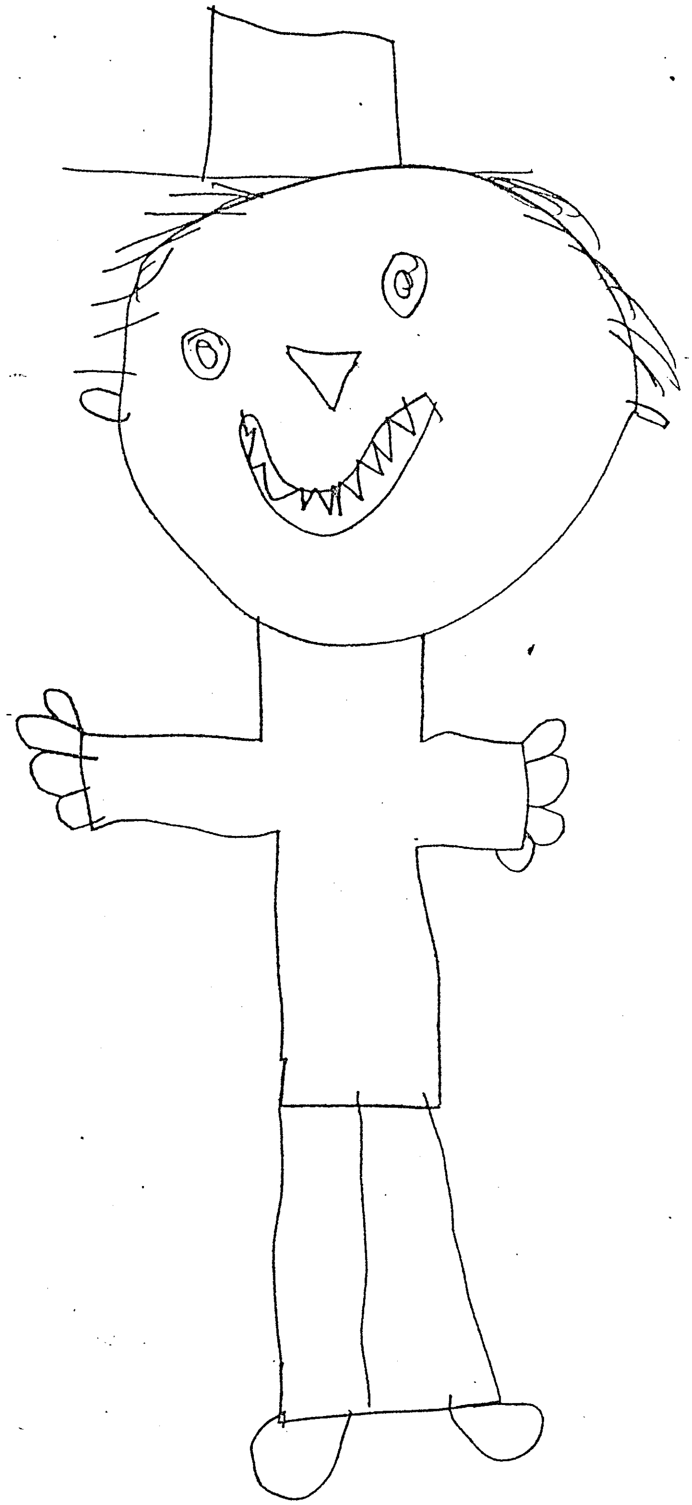


Boy 7y 7m.
6th percentile.

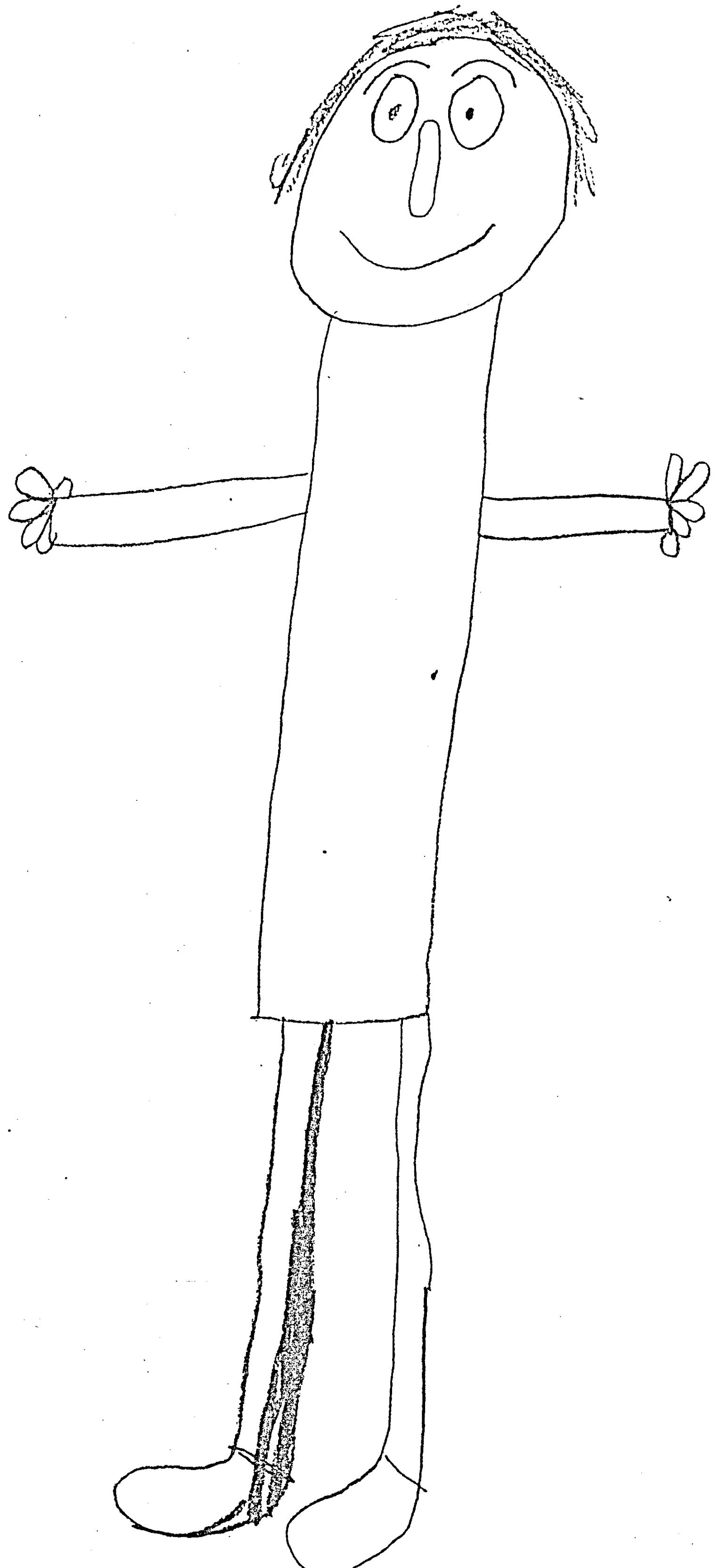
Case Study Children.

Child I

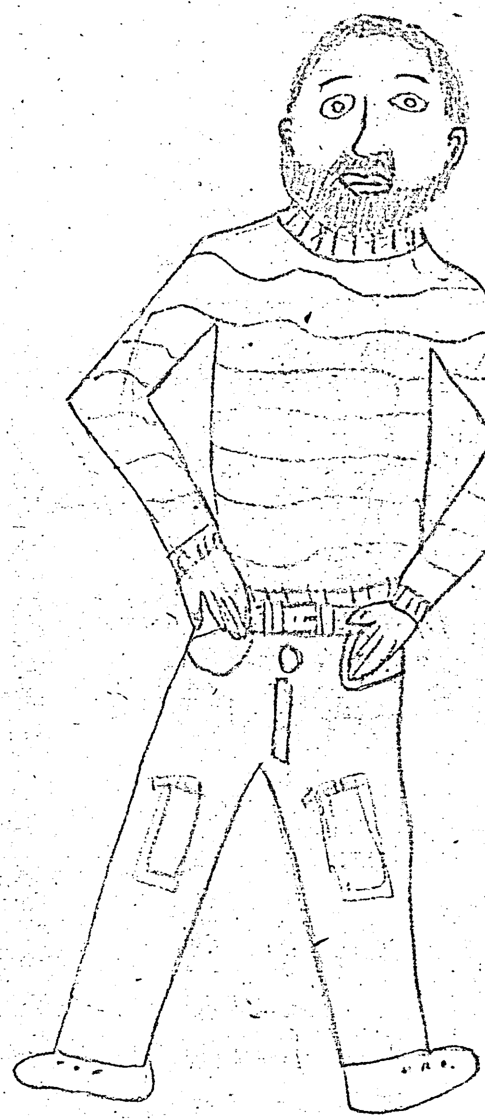
Girl 8yrs.
5th percentile.



E.S.N.(M) Boy. 8yrs. 12th Percentile.
(A child with Motor Development problems)



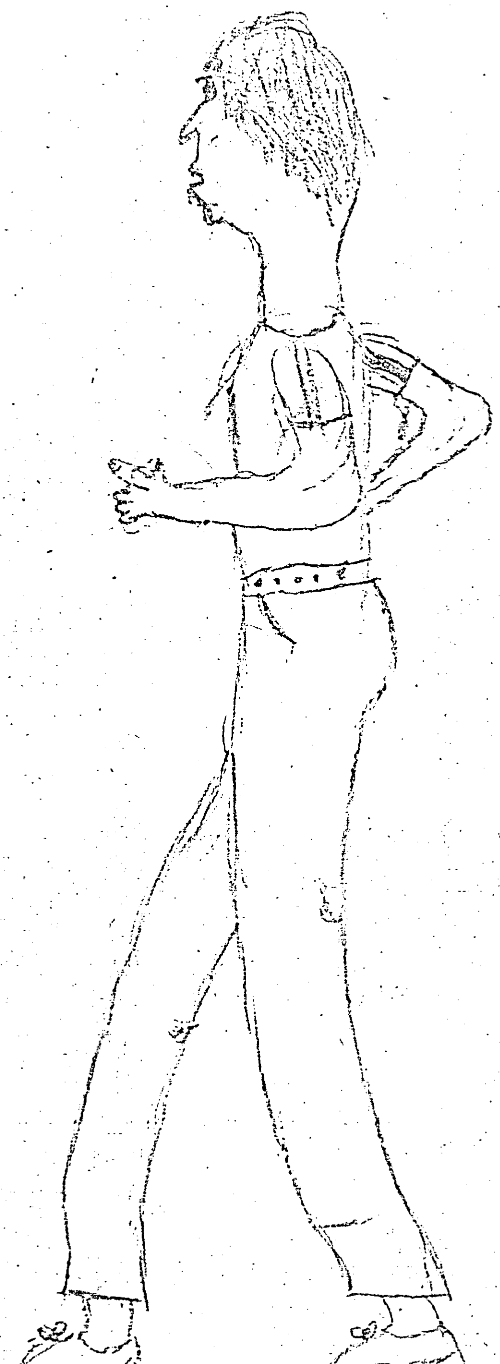
E.S.N. (M) Boy. 8yrs. 19th percentile.



Girl 8y+8m.

99th Percentile

Boy. 9y. 3m.
99th Percentile.



APPENDIX FOUR.

Some examples of worksheets which combine number recognition and figure-ground discrimination, for use with the type of child considered in this study.

(Gallagher 1978)

Each of these pictures would be presented separately to the child.